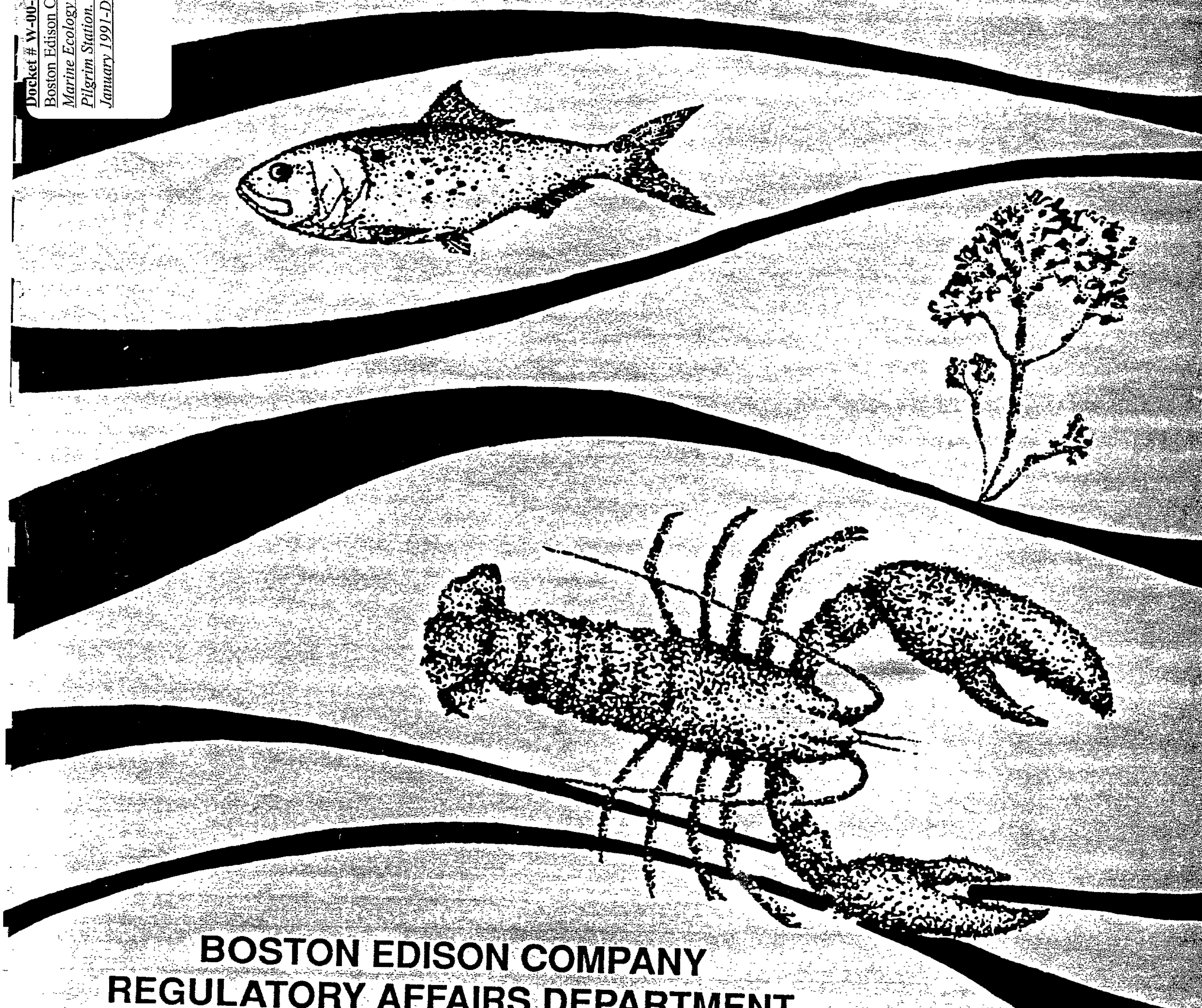
25825. Intake-case studies - Pilgrim #2

marine ecology studies
Related to Operation of Pilgrim Station

Docket # W-00-32 DCN: 4-1365 1365
Boston Edison Company.
Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 39.
January 1991-December 1991.

SEMI-ANNUAL REPORT NUMBER 39
JANUARY 1991 – DECEMBER 1991



BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT
LICENSING DIVISION

371 p.

BOSTON EDISON
800 Boylston St. Boston, MA 02199

MARINE ECOLOGY STUDIES

RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 39

REPORT PERIOD: JANUARY 1991 THROUGH DECEMBER 1991

DATE OF ISSUE: APRIL 30, 1992

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April 29, 1992
BECo 92-050

E. J. Wagner
Vice President
Nuclear Engineering

NPDES Program Operations Section (WCP)
Environmental Protection Agency
P.O. Box 8127
Boston, MA 02114

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

Dear Sirs:

In accordance with Part I, Paragraphs A.8.b & e, and Attachment A, Paragraph I.F, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557 (Federal) and No. 359 (State), Semi-Annual Marine Ecology Report No. 39 is submitted. This covers the period from January through December 1991.

E T Boulette

E. J. Wagner

Attachment: Semi-Annual Marine Ecology Report No. 39

RDA/cab/6287

T. E. LANDRY
MAY 12 1992

MAY 11 92

BOSTON EDISON
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Vice President
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April 29, 1992
BECo 92-050

Mass. Division of Water Pollution Control
Regulatory Branch - 7th Floor
One Winter Street
Boston, MA 02108

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

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E T Boulitto fo.
E. J. Wagner

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RDA/cab/6287

cc: Mass. Division of Water Pollution Control
Lakeville Hospital
Lakeville, MA 02346

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SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January - December 1991) are presented below. (Note: PNPS was operating at normal power level from January - December 1991 with the exception of outages during most of the May-August period and in November.)

Marine Fisheries Monitoring:

1. In the mid May-August 1991 shorefront sportfish survey at Pilgrim Station, 1,492 angler visits accounted for 900 fishes caught. Bluefish (71%) and cunner (27%) dominated the sportfish catch. The presence of a strong thermal discharge component during most of 1990 and 1991 resulted in good sportfishery success compared with outage and low power years covering the shorefront angling season.

2. Pelagic fish mean CPUE (Catch Per Unit Effort) for 1991 at the gill net station (82.3 fishes/set) increased 20% from 1990 to the second lowest level recorded since 1971. Pollock (41%) and Atlantic herring (23%) were 64% of the total catch. Both Atlantic herring and pollock increased from 1990. A significant positive correlation was found for cunner catch (third highest in 1991) and seasonal, Pilgrim Station operational output (thermal loading to the environment) prior to 1985.

3. Shrimp trawl catch for 1991 recorded 21 benthic fish species with Atlantic herring (60%), winter flounder (15%), and little skate (9%) composing 84% of the total. Mean CPUE for all species was 0.1 (lowest) at the Warren Cove station, 10.4 (highest) at the Priscilla Beach station and 3.9 (same as 1990) for all stations pooled in 1991. The presence of a large number of Atlantic herring caught off Priscilla Beach during one trawl made in the spring influenced CPUE index interpretations.

4. Adult lobster mean monthly catch rate per pot haul, in May - October 1991, was 0.37 lobsters which is 16% lower than the 1990 rate (0.44). The surveillance area (thermal plume) catch rate was 0.35 while the reference area (control) was also 0.35. A significant negative correlation was noted between legal lobster catch rate for thermal plume areas, and mean seasonal (May - November) Pilgrim Station output for the period from 1973 - 1983, but not when 1985, 1990 and 1991 data were included. The legal lobster catch rate for preoperational/outage years has not been significantly lower in the thermal plume area than in control areas. The lobster research study, which commenced in 1986, found significant negative correlations between plant MDC and sublegal catch rates at stations closest to the discharge canal and no significant relationship between Pilgrim operation and legal catch in 1991.

5. In May - October 1991 fish observational dive surveys, 8 species were observed in the thermal plume area. Cunner (64%), striped bass (13%), bluefish (11%) and tautog (10%) were the most numerous fishes seen, the latter three species being most abundant in the direct path of the Pilgrim discharge current. Total number of fishes observed was 25% lower than in 1990. Most fishes were in greatest concentrations at stations in the discharge zone (61%), followed by the control zone (28%) and the stunted zone (10%). These results were different than 1984/1987/1988 (outage years with reduced discharge current), when most fish were observed relatively evenly divided between discharge and control zones, and similar to 1985/1986/1989/1990 (higher discharge current years) when fish seemed to greatly favor being in the path of the effluent.

6. Atlantic silverside accounted for 46% of the 1991 haul seine (shore zone) fish catch with a total of 27 species collected. The PNPS intake showed higher species diversity compared to exposed coastal stations. Fish captured in the PNPS intake embayment were greatly dominated by Atlantic nerring, particularly during early summer when a large school of jiuveniles accounted for a major fish impingement incident. A deeper seine net (10' compared to 6'), to more effectively sample the intake, was utilized beginning in 1984 and results have generally indicated this area is more similar in fish fauna attraction to an estuary than exposed coastal areas.

7. A total of 738 cunner were tagged in 1990/1991 and 53 (7%) recovered in the Pilgrim incinity. Time at large and locations of recovered fish indicate that movement of this species is local which reflects its residential nature.

Impingement Monitoring:

1. The mean January - December 1991 impingement collection rate was 6.27 fish/hr. The rate ranged from 0.18 fish/hr (August) to 24.57 fish/hr (July) with Atlantic herring comprising 75.4% of the catch, followed by Atlantic silverside 8.7%, Atlantic menhaden 3.6%, winter flounder 2.1% and grubby 1.5%. Fish impingement rates in 1985, 1986 and 1989 - 1991 were several times higher than in 1984, 1987 and 1988 when Pilgrim Station outages had both circulating water pumps off for various periods of time.

2. In June and July 1991, Atlantic herring impingement accounted for 98% of this species annual collection. They have been the most abundant species impinged on an annual basis at Pilgrim Station in only two other years, 1986 and 1976.

3. A large, fish impingement incident was noted from July 22-25 when a rate of 52.29 Atlantic herring/hr. was recorded, resulting in an estimated mortality of over 4,000 juveniles.

4. The mean January - December 1991 invertebrate collection rate was 1.40+/hr with jellyfish and blue mussels dominating, and common starfish and sevenspine bay shrimp accounting for 25.4% and 22.3% of the enumerated catch, respectively. Fifty-four

American lobsters were sampled. The invertebrate impingement rates in 1985, 1986 and 1989 - 1991 were similar to those recorded at Pilgrim Station during the 1987 and 1988 outage years, despite lower circulating water pump availability in the outage years.

5. Impinged fish, initial survival at the end of the Pilgrim Station intake sluiceway was approximately 57% during static screen washes and 50% during continuous washes. Three of the dominant species showed greater than 50% survival, overall.

Fish Surveillance:

Fish overflights in 1991 spotted all four major species categories: herring, Atlantic menhaden, Atlantic mackerel and baitfish. Eight sightings of fish in the nearfield Pilgrim vicinity were made, mostly Atlantic herring. On both August 15 and 24 over 100,000 pounds of this species, and on June 26 300,000 pounds of menhaden, were observed within a few miles of Pilgrim Station. None of these occurrences were reported to regulatory authorities as they were not within 1/2 mile of the discharge canal.

Benthic Monitoring:

1. No new taxa of invertebrates were added to the list of biota for PNPS benthic surveys as a result of analysis of the 1991 samples. A total of 107 species were recorded (28% polychaetes, 28% mollusks, 32% crustaceans).

2. No notable difference in species richness existed between the Effluent and Reference stations based on results of fall 1988 - spring 1991 sampling. The reference stations, which have characteristically ranked ahead of the Effluent station in species numbers, appeared more similar to the discharge area in late 1988 - early 1991 indicating a lack of response to PNPS thermal effluent effects. Habitat modifications by mussel population fluctuations may account, inpart, for the highest number of species recorded anywhere, at the effluent station in fall 1991.

3. Review of overall faunal community structure, via cluster analysis, showed that the Effluent Station had a low degree of similarity compared with the reference stations in spring 1991, but higher in the fall. In contrast, faunal clusterings and algal community overlap/biomass values showed a general recovery of benthic community structure at the Effluent site compared with reference sites during the three year outage ended in early 1989.

4. The warm-water species, <u>Gracilaria</u> <u>tikvahiae</u>, decreased in the area of the Effluent station during 1986, was completely absent in 1987 and 1988, and reappeared in the fall of 1989 - 1991 during PNPS operation. It was also rare in 1984, before it normally colonized in 1985, indicating a direct relationship to the lack of thermal effluent in 1984, 1986, 1987 and 1988. Additional evidence of PNPS impacts in the Effluent discharge zone was the prevalent appearance of the cold-water alga,

Laminaria, in the Effluent area only during outage years (1984, 1987, 1988) and the spring of 1989 transect surveys.

5. Four observations of the near-shore acute impact zones were performed during this reporting period. Denuded and stunted zone boundaries were indistinquishable during September 1987 – June 1989 discharge surveys as a result of the PNPS shutdown. These surveys noted delineated, denuded impact areas in fall 1989 - 1991, primarily because two circulating water pumps were in operation most of the time, resulting in maximum discharge current flow. The area of PNPS-induced scouring impacts varied from 1,080 m^2 (October) to 1,320 m^2 (March) in 1991.

Entrainment Monitoring:

1. A total of 34 species of fish eggs and/or larvae were found in the January - December 1991 entrainment collections (21-eggs, 30-larvae).

2. Seasonal egg collections for 1991 were dominated by Atlantic cod and American plaice (winter – early spring); Atlantic mackerel and labrids (late spring – early summer); windowpane and rockling/hakes (late summer - autumn).

3. Seasonal larval collections for 1991 were dominated by rock gunnel and sculpin (winter - early spring); Atlantic mackerel and radiated shanny (late spring – early summer); cunner and fourbeard rockling (late summer – autumn).

4. No lobster larvae were collected in the entrainment samples for 1991.

5. In 1991 an estimated 1.326×10^9 fish eggs and 2.887×10^8 fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated by Atlantic mackerel and the labrid - Pleuronectes group, and larvae by cunner and sculpin spp.

6. Total numbers of fish larvae collected for similar volumes of water sampled, in spring and summer 1984 and 1987, were noteably lower than for the similar periods in 1983, 1985, 1986 and 1988 - 1991. These results were shown significant to the fact that both Pilgrim Station circulating water pumps were offline during most of the spring/summer period 1984/1987, but at least one circulating water pump was operating during the majority of this period in the other years.

7. On no occasions in 1991 were "unusually abundant" ichthyoplankton densities recorded in samples, as defined by the entrainment contingency sampling plan.

INTRODUCTION

A. Scope and Objective

This is the thirty-nineth semi-annual report on the status and results of the Environmental Surveillance and Monitoring Program related to the operation of Pilgrim Nuclear Power Station (PNPS). The monitoring programs discussed in this report relate specifically to the Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the twenty-seventh semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES Permit from the U.S. Environ-mental Protection Agency (#MA0003557) and Massachusetts Division of Water Pollution Control (#359). A multi-year (1969-1977) report incorporating marine fisheries, benthic, plankton/entrainment and impingement studies was submitted to the NRC in July 1978, as required by the PNPS Appendix B Tech. Specs. Programs in these areas have been continued under the PNPS NPDES permit. Amendment #67 (1983) to the PNPS Tech. Specs. deleted Appendix B non-radiological water quality requirements as the NRC felt they are covered in the NPDES Permit.

The objectives of the Environmental Surveillance and Monitoring Program are to determine whether the operation of PNPS results in measurable effects on the marine ecology and to evaluate the significance of any observed effects. If an effect of significance is detected, Boston Edison Company has committed to take steps to correct or mitigate any adverse situation.

These studies are guided by the Pilgrim Administrative-Technical Committee (PATC) which was chaired by a member of the Mass. Division of Water Pollution Control in 1991, and whose membership includes representatives from the University of Massachusetts, the Mass. Division of Water Pollution Control, the Mass. Division of Marine Fisheries, the National Marine Fisheries Service (NOAA), the Mass. Office of Coastal Zone Management, the U.S Environmental Protection Agency and Boston Edison Company. Copies of the Minutes of the Pilgrim Station Administrative-Technical Committee meetings held during this reporting period are included in Section V.

B. Marine Biota Studies

1. Marine Fisheries Monitoring

A modified version of the marine fisheries monitoring, initiated in 1981, is being conducted by the Commonwealth of Massachusetts, Division of Marine Fisheries (DMF).

The occurrence and distribution of fish around Pilgrim Station and at sites outside the area of temperature increase are being monitored. Pelagic species were sampled using gill net (1 station) collections (Figure 1) made at monthly intervals. In 1981, shrimp trawling and haul seining were initiated which provide more PNPS impact-related sampling of benthic fish and shore zone fish, respectively. Shrimp trawling was done once/month (January - March) and twice/month (April - December) at 4 stations (Figure 2) and haul seining twice/month during June - November at 4 stations (Figure 1).

Monitoring is conducted for local lobster stock catch statistics in areas in the proximity of Pilgrim Station (Figure 4). Catch statistics are collected approximately biweekly throughout the fishing season (May-November).

A finfish observational dive program was initiated in June 1978. SCUBA gear is utilized on biweekly dives from May-October (weekly mid-August to mid-September) at 6 stations (Figure 2) in the PNPS thermal plume area.

In 1986, an experimental, lobster pot trawl monitoring effort was initiated to eliminate any biases associated with the collection of lobster stock catch statistics for determining PNPS effects. Ten 5-pot lobster trawls were fished in the thermal plume and control areas around PNPS during 1991 (Figure 3).

Results of the marine fisheries monitoring during the reporting period are presented in Section IIIA.1 and IIIA.2.

2. Benthic Monitoring

The benthic monitoring described in this report was conducted by Scientific Applications International Corporation, Woods Hole, Massachusetts.

The benthic flora and fauna were sampled at three locations at depths of 10 feet (MLW) (Figure 1). Quantitative (rock substratum) samples were collected, and the dominant flora and fauna in each plot were recorded. Sampling was conducted two times per year (March and September) to determine biotic changes, if any.

Transect sampling off the discharge canal to determine the extent of the denuded and stunted zones is conducted four times a year (March, June, September and December).

Results of the benthic surveys and impact analysis during this period are discussed in Section IIIB.1 and IIIB.2.

3. Plankton Monitoring

Marine Research, Inc. (MRI) of Falmouth, Massachusetts, has been monitoring entrainment in Pilgrim Station cooling water of fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zooplankton were also studied). Figure 5 shows the entrainment contingency sampling station locations to be sampled should the number of eggs/larvae entrained greatly exceed recorded historical averages. Information generated through this monitoring has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effects of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the PATC on the basis of the program results. Plankton monitoring in 1991 emphasized consideration of ichthyoplankton entrainment. Results of the ichthyoplankton entrainment monitoring and impact analysis for this reporting period are discussed in Section IIIC.1 and IIIC.2.

4. Impingement Monitoring

The Pilgrim Station impingement monitoring and survival program speciates, quantifies and determines viability of the organisms carried onto the four intake traveling screens. Since January 1979, Marine Research, Inc. has been conducting impingement sampling with results being reported on by Boston Edison Company.

A new screen wash sluiceway system was installed at Pilgrim in 1979 at a total cost of approximately $150,000. This new sluiceway system was required by the U.S. Environmental Protection Agency and the Mass. Division of Water Pollution Control as a part of NPDES Permit #MA0003557. Special fish survival studies conducted from 1980-1983 to determine its effectiveness in protecting marine life were terminated in 1984, and a final report on them appears in Marine Ecology Semi-Annual Report #23.

Results of the impingement monitoring and survival program, as well as impact analysis, for this reporting period are discussed in Section IIID.

C. Fish Surveillance Studies

March - November, weekly fish spotting overflights were conducted as part of a continuing effort to monitor the times when large concentrations of fish might be expected in the Pilgrim vicinity.

An annual summary report for this effort for 1991 is presented in Section IVA.

D. Station Operation History

The daily average, reactor thermal power levels from January through December, 1986-1991 are shown in Figure 6. As can be seen, PNPS was in an operating stage during most of this reporting period with a 1991 capacity factor (MDC) of 58.4%. Cumulative capacity factor from 1973-1991 is 47.4%.

E. 1992 Environmental Programs

A planning schedule bar chart for 1992 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1991 - June 1993, is included as Figure 7. Both marine fisheries haul seine and benthic quantitative monitoring activities were terminated in 1992.

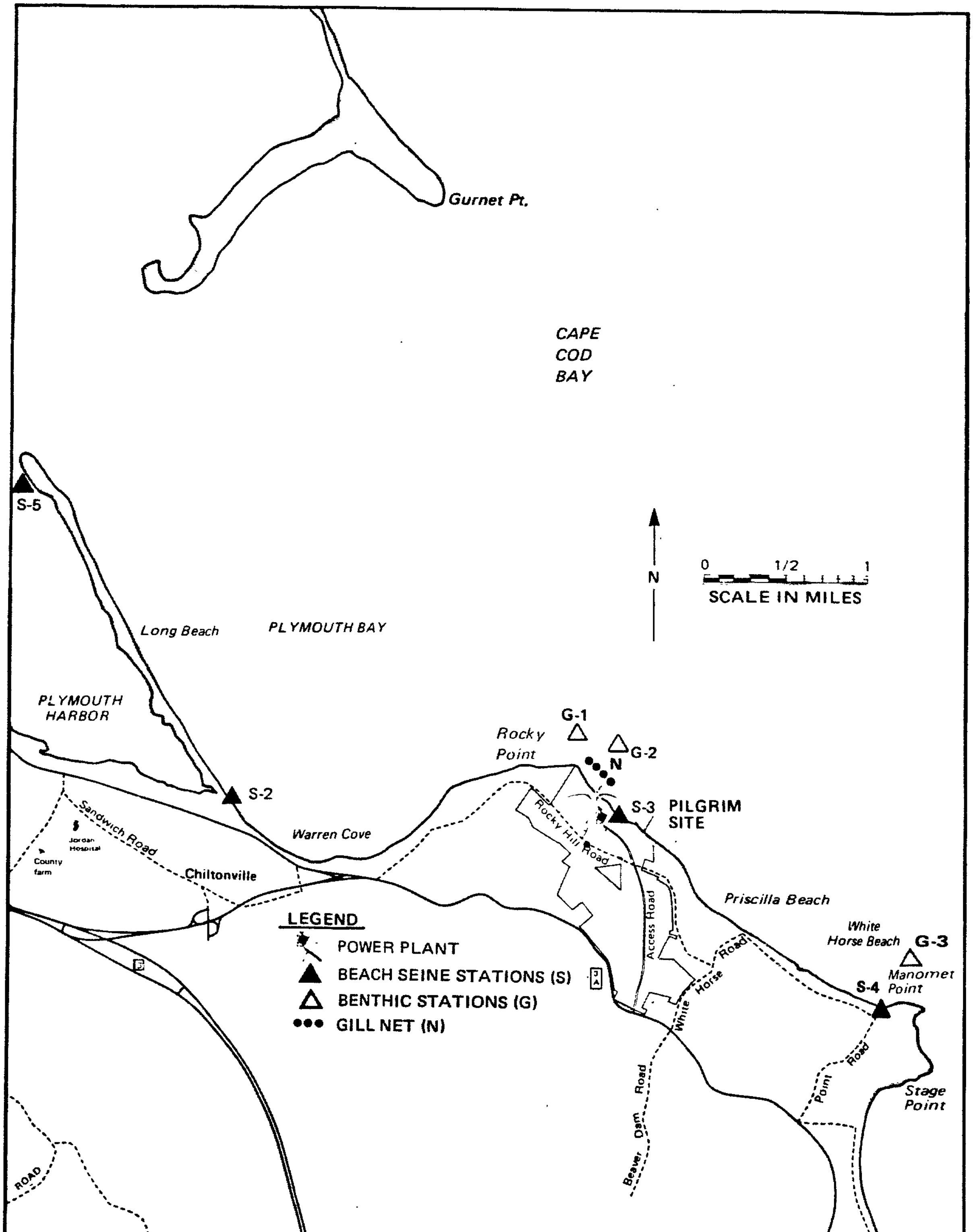

Figure 1. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

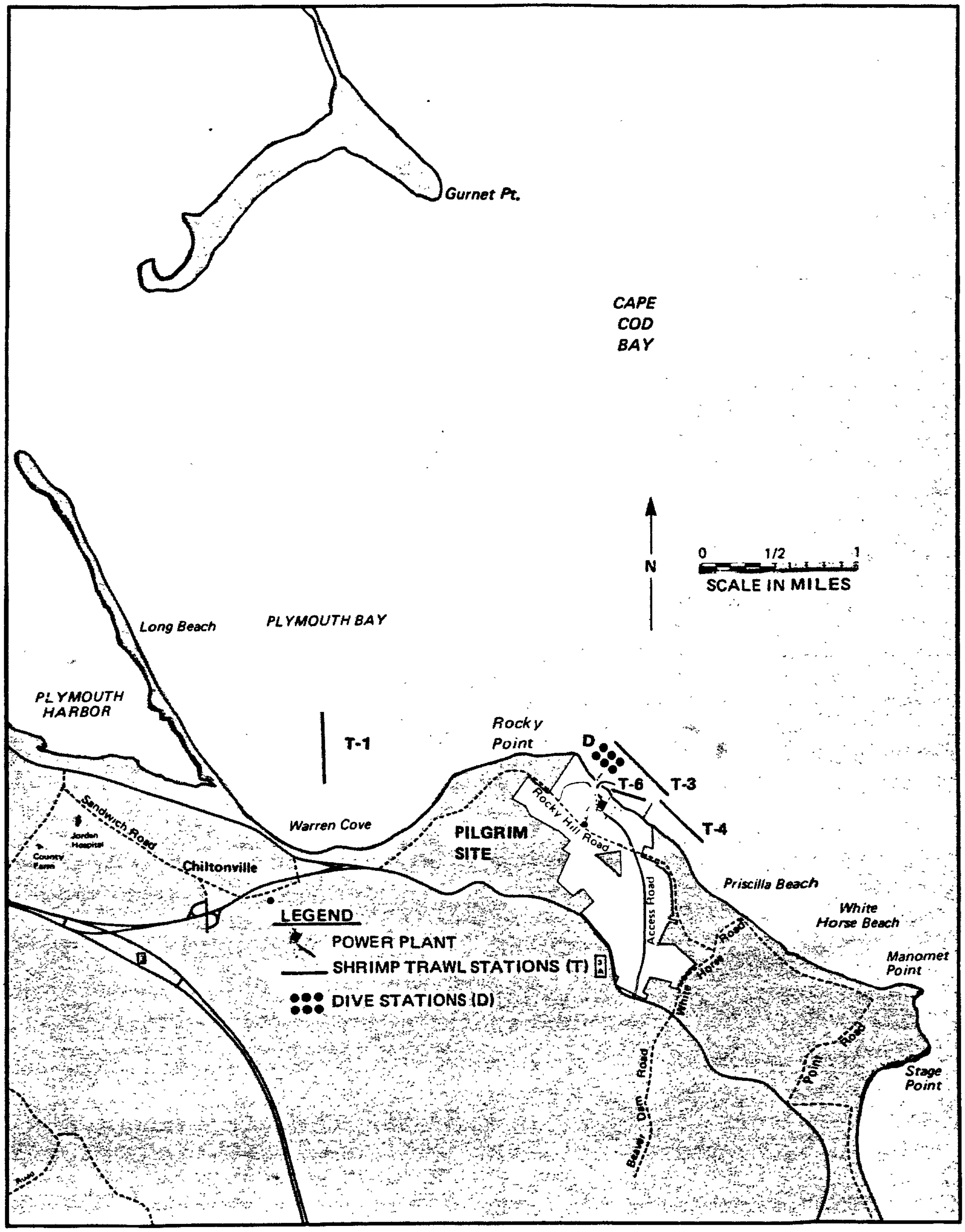

Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

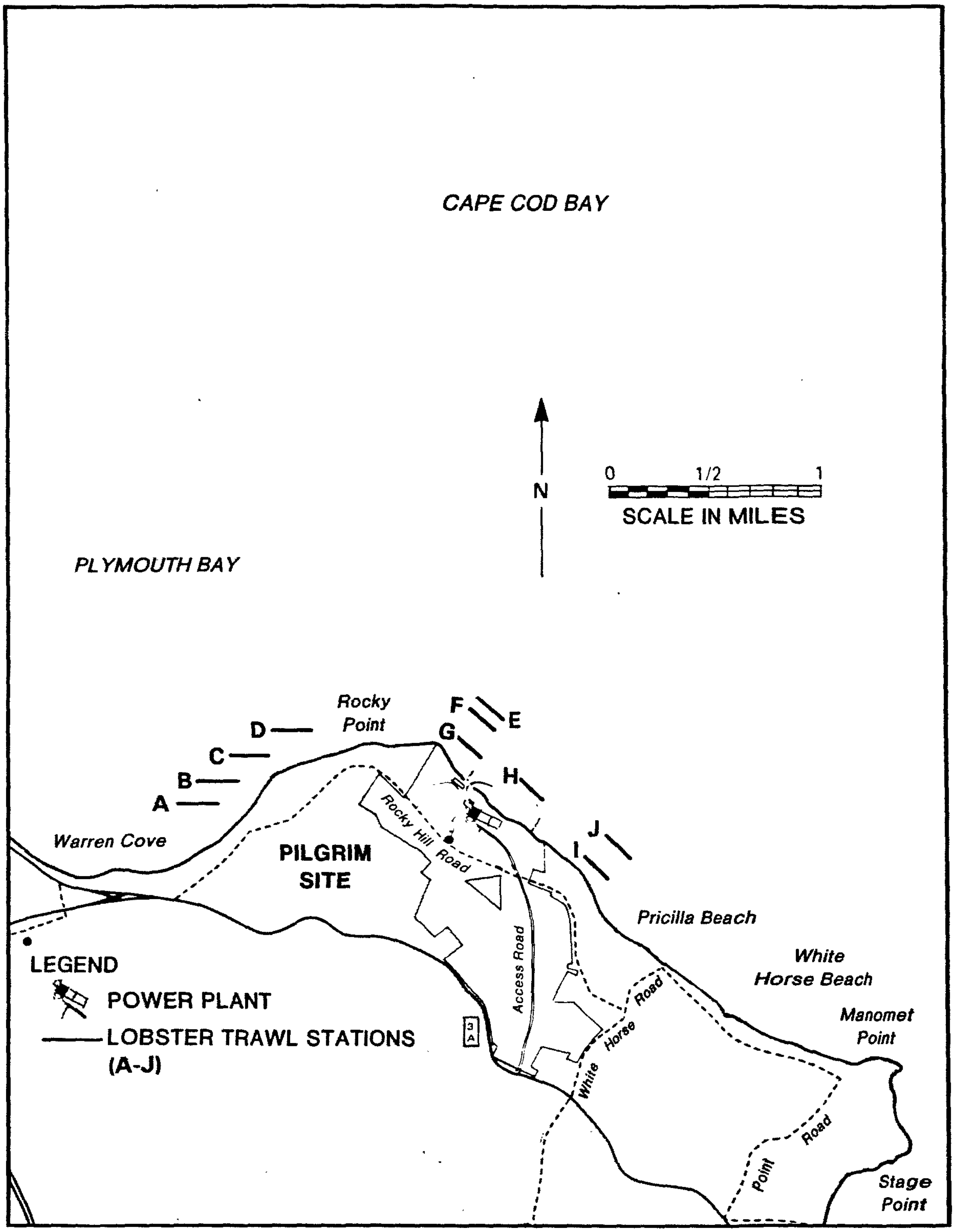

Figure 3. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

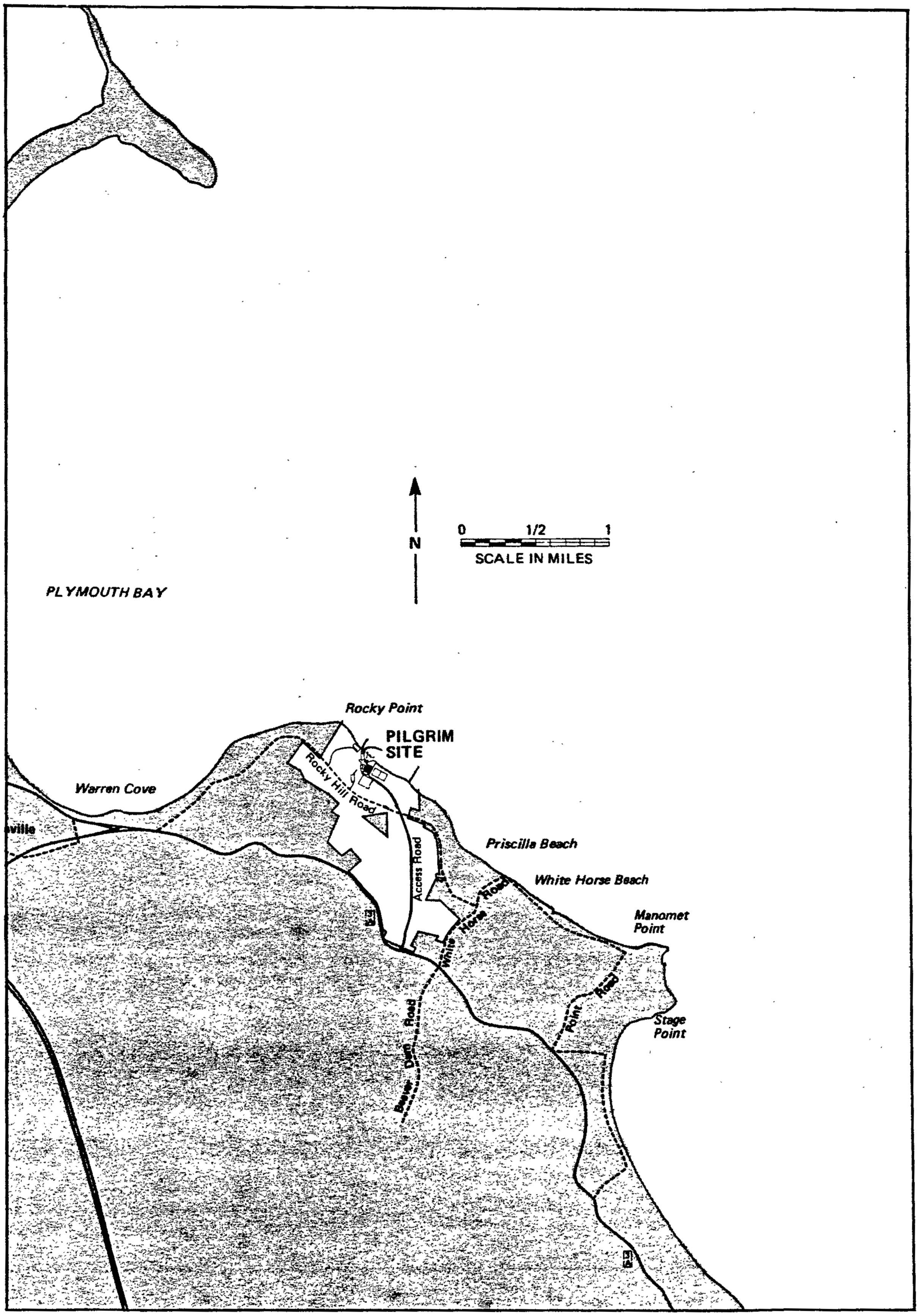

Figure 4 Lobster Pot Sampling Grid for Marine Fisheries Studies.

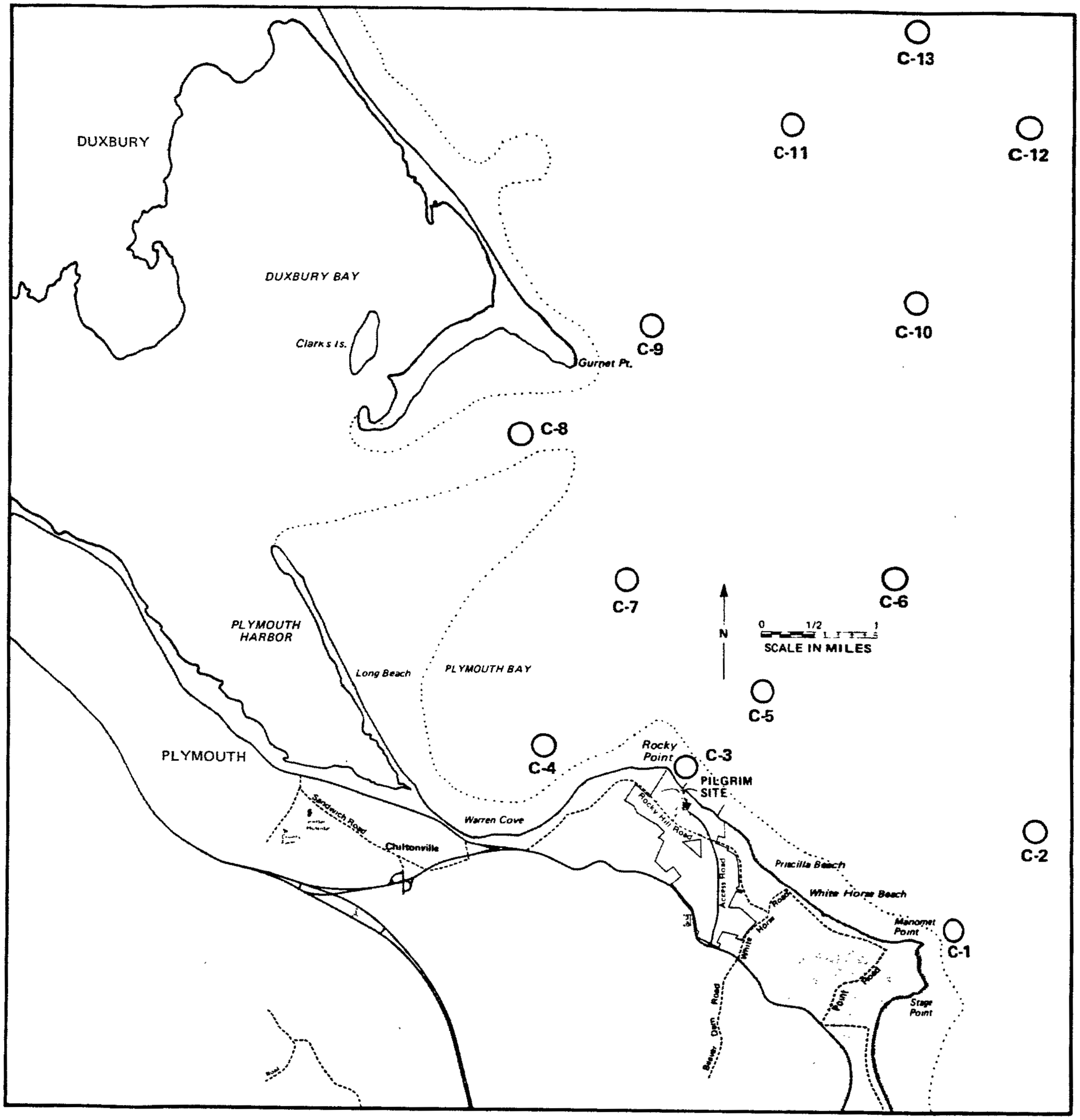

Figure 5 Location of Entrainment Contingency Plan Sampling Stations, C.

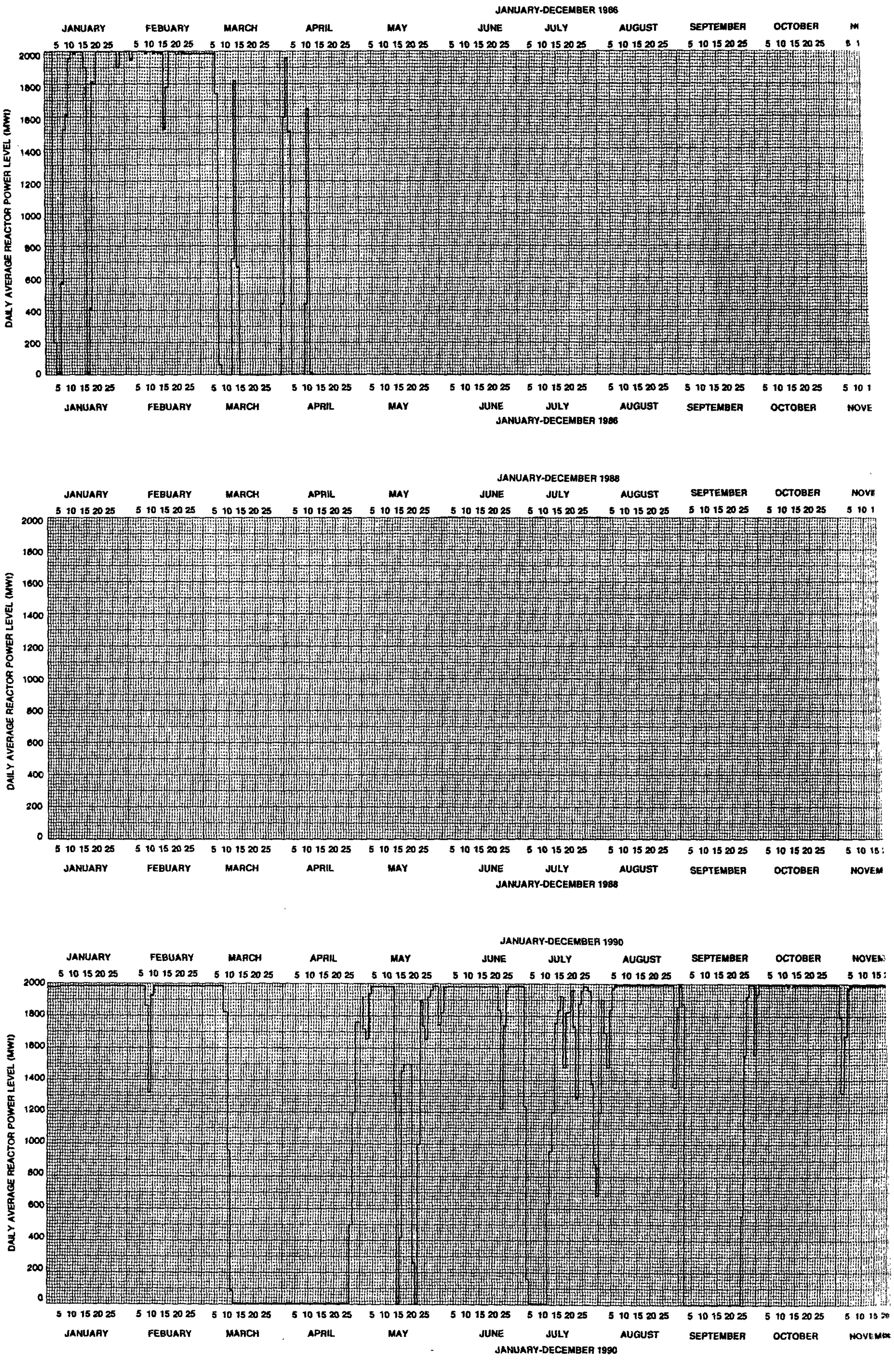

FIGURE 6. Daily Average Rea
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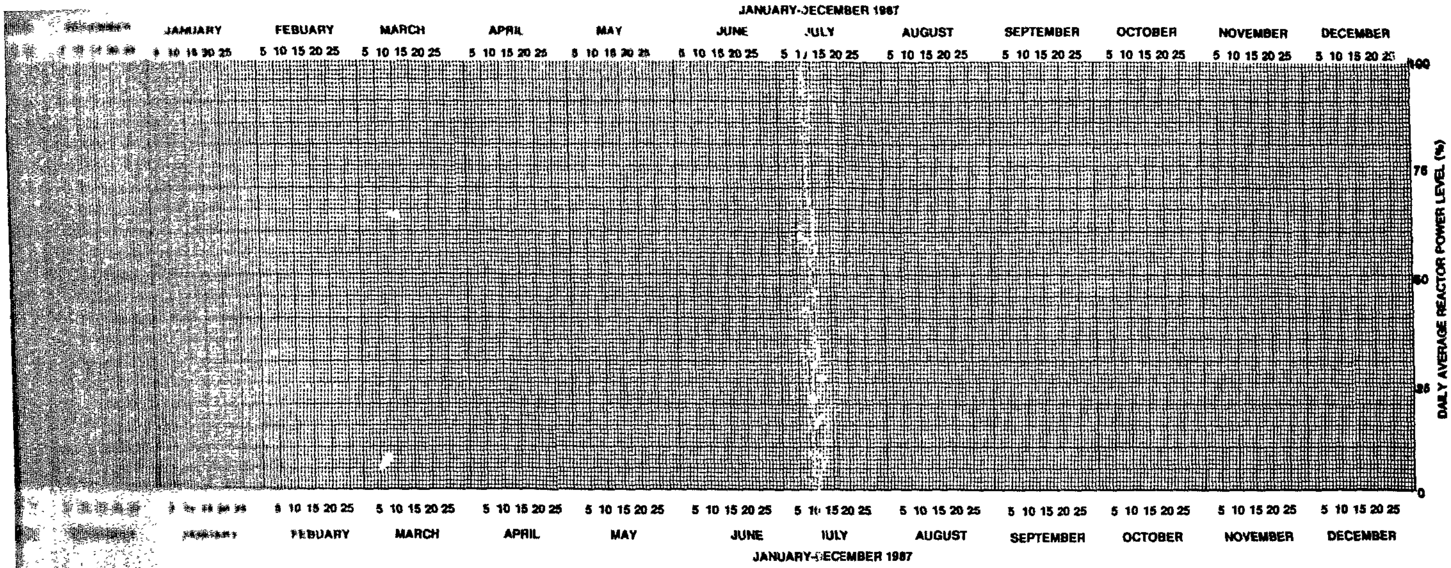

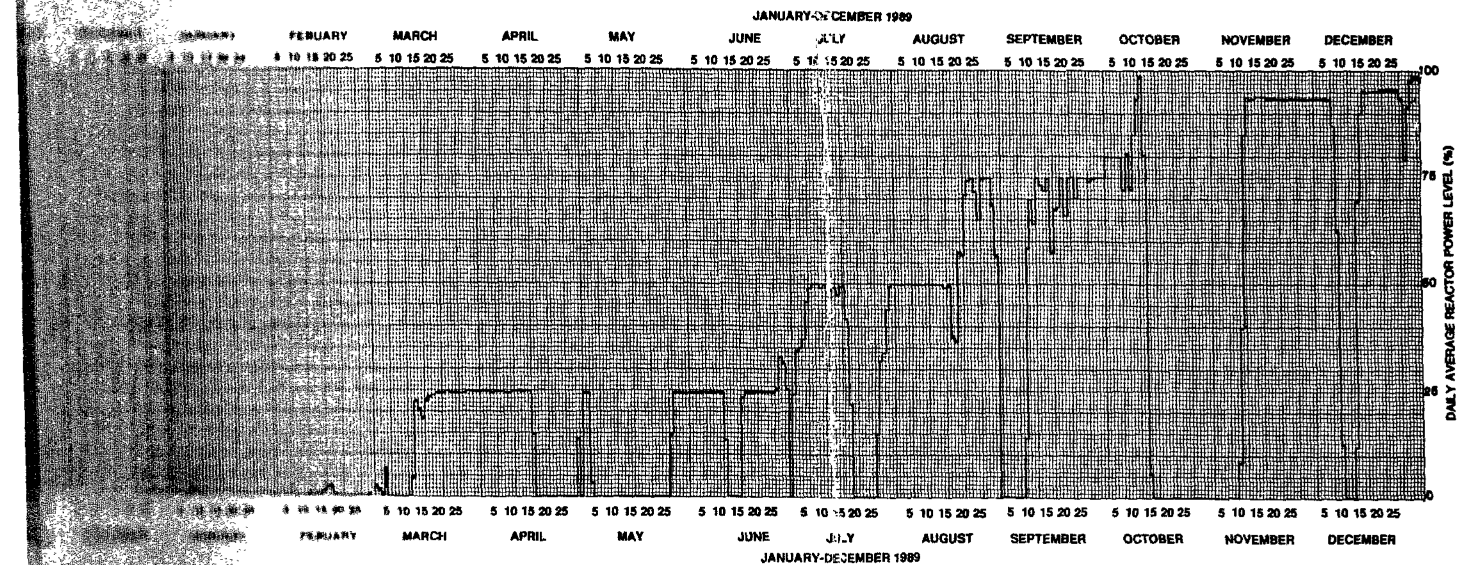

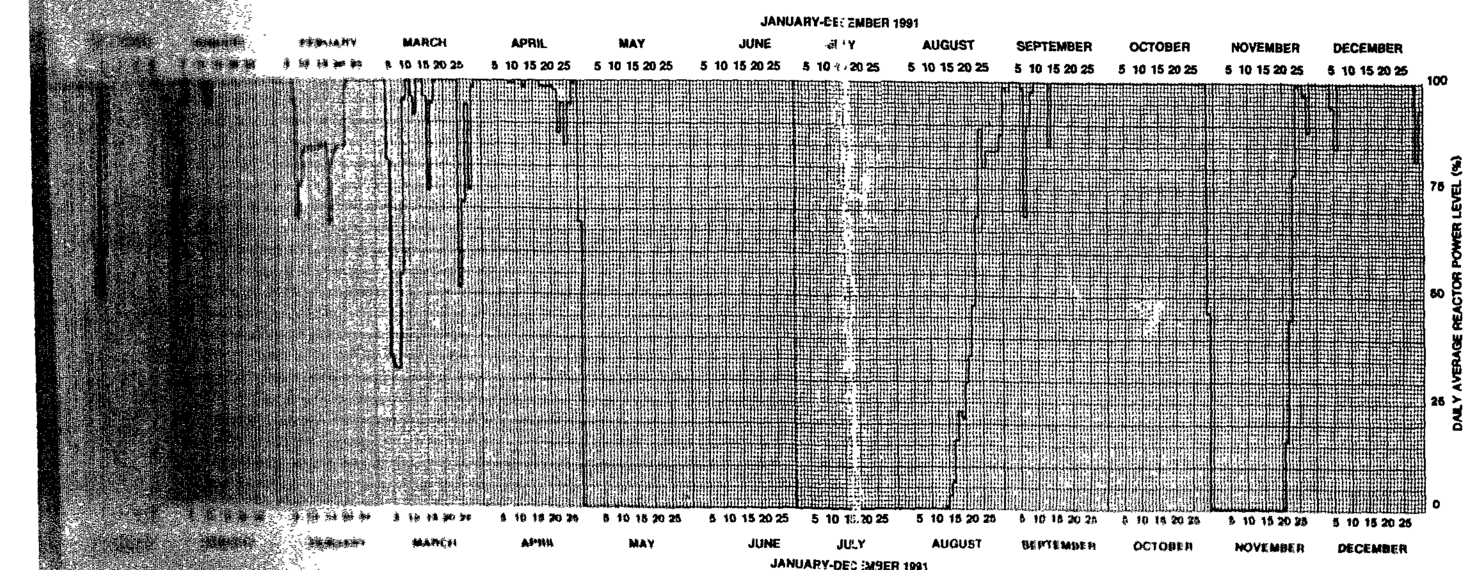

[illegible] Thermal Power Level (MW_t and %) from
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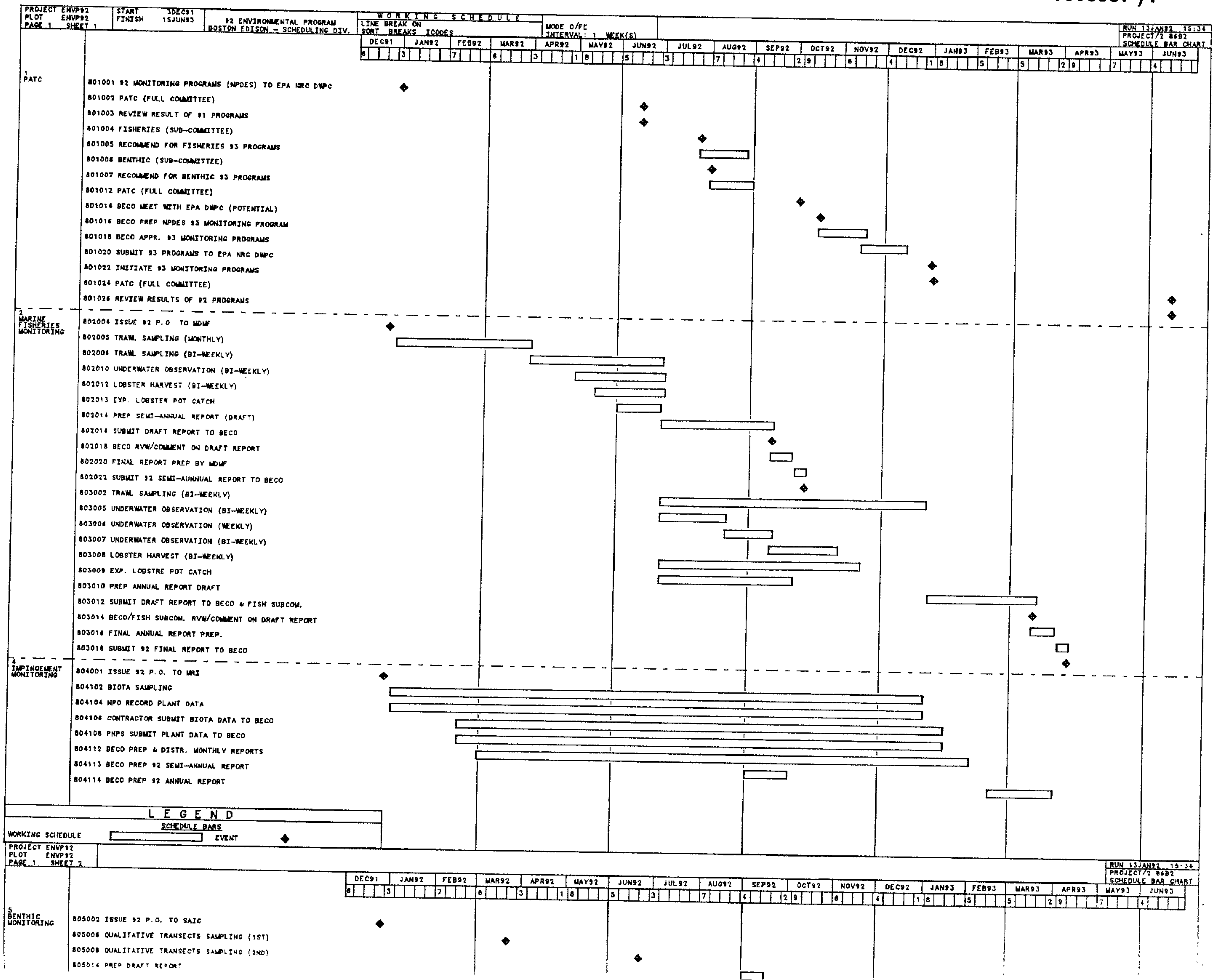
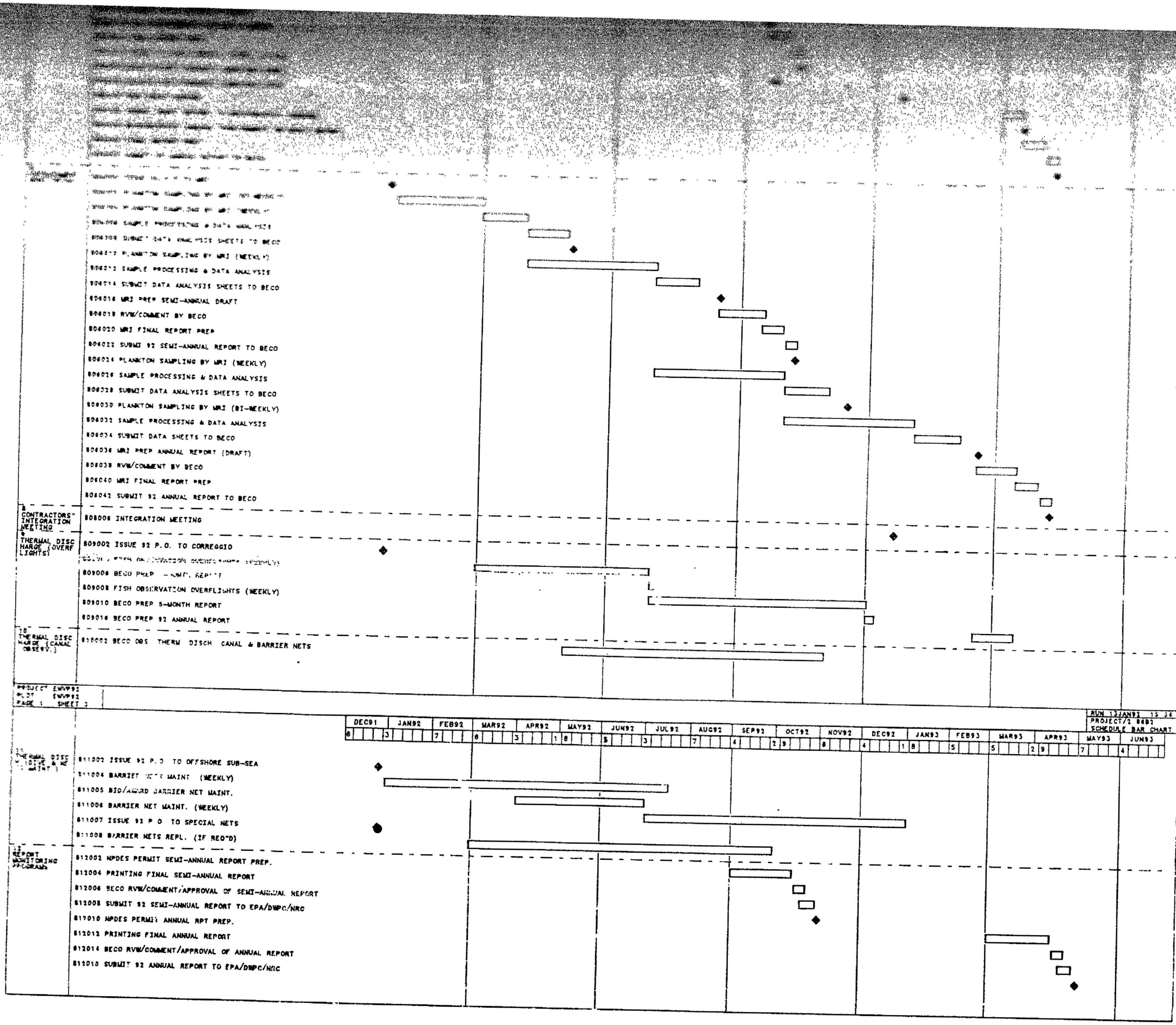
Figure 7. Schedule for Pilgrim Station 1992 Environmental Monitoring Programs (NPDES Permit # MA0003557) .




806010 PLANKTON SAMPLING BY MRI (WEEKLY)
806012 SAMPLE PROCESSING & DATA ANALYSIS
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806016 MRI PREP SEMI-ANNUAL DRAFT
806018 RVW/COMMENT BY BECO
806020 MRI FINAL REPORT PREP
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806024 PLANKTON SAMPLING BY MRI (WEEKLY)
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809016 BECO PREP 92 ANNUAL REPORT
10 THERMAL DISCHARGE (CANAL OBSERV.)
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811006 BARRIER NET MAINT. (WEEKLY)
811007 ISSUE 92 P.O. TO SPECIAL NETS
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12 REPORT MONITORING PROGRAMS
812002 NPDES PERMIT SEMI-ANNUAL REPORT PREP.
812004 PRINTING FINAL SEMI-ANNUAL REPORT
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812008 SUBMIT 92 SEMI-ANNUAL REPORT TO EPA/DWPC/NRC
812010 NPDES PERMIT ANNUAL RPT PREP.
812012 PRINTING FINAL ANNUAL REPORT
812014 BECO RVW/COMMENT/APPROVAL OF ANNUAL REPORT
812016 SUBMIT 92 ANNUAL REPORT TO EPA/DWPC/NRC

ANNUAL REPORT
ON
ENVIRONMENTAL IMPACT MONITORING
OF
PILGRIM NUCLEAR POWER STATION

(CHARACTERIZATION OF THE MARINE FISHERIES RESOURCES)

Project Report No. 52 (January-December, 1991)

(Volume 1 of 2)

By

Robert P. Lawton, Brian C. Kelly,
Vincent J. Malkoski And Mando Borgatti

April 6, 1992
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
Division of Marine Fisheries
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Boston, Massachusetts 02202

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I. EXECUTIVE SUMMARY

A modified version of marine fisheries monitoring for Pilgrim Nuclear Power Station, initiated in 1981, was conducted by the Massachusetts Division of Marine Fisheries in 1991. The occurrence, distribution, and relative abundance of finfish and lobster were monitored according to standardized sampling schemes to identify trends and relationships in the sampling data collected from the study area over time. We focused our efforts on commercially and recreationally important fisheries resources. Nearshore bottom trawling, haul seining, experimental gill-net sampling, monitoring of local commercial lobster catch statistics, experimental lobster trapping, observational diving, and a sportfishing creel survey rounded out investigations.

Catch rates in the Pilgrim area declined from 1990 to 1991 for the top three groundfish (winter flounder, little skate, and windowpane) trawled. The gill-net catch of pollock, Atlantic herring, and cunner increased from last year. Seine catch rates of Atlantic silverside and juvenile Atlantic herring increased substantially from last year. The overall number of fish sighted during the diving study decreased, due to a substantial decline in the relative abundance of tautog. Angling effort at the Shorefront increased, with sportfish catches nearly doubling last year's total. Tagging returns have suggested there is limited summer movement of cunner off the outer intake breakwater. Total lobster catch rates in both the experimental and commercial studies leveled off this year, with legal catch rates declining slightly, and sublegal rates increasing.

II. INTRODUCTION

A marine monitoring program was conducted in 1991 by the Massachusetts Division of Marine Fisheries (DMF) to assess impact of Pilgrim Nuclear Power Station (PNPS), under Purchase Order No. 68004 to Boston Edison Company (BECo). Our sampling employs various gear types and strategies that characterize the lobster and numerous finfish populations present in the Pilgrim area. With each sampling gear, the pairing of an impacted station or stations with comparable reference station(s) is a prime consideration when collecting sampling data. When possible, we have established more than one reference station. Reference site data are needed to address natural changes in populations versus those caused by anthropogenic impacts.

We collected data on the occurrence, distribution, and relative abundance of lobster and various finfish species, following a standardized sampling regime. Measurements, counts, percentages, and indices are used, and statistical tests run in the analyses.

This report (Volume 1) focuses on fisheries resources in the Pilgrim area as a whole. Essential findings are presented; however, detailed data presentations, including statistical tests and supportive data, are available upon request. The intent is to condense subject matter but maintain clarity of data reporting and interpretation in a comprehensive manner.

III. METHODS AND MATERIALS

Commercial Lobster Catch

Commercial and recreational lobstermen harvest the American lobster in the environs of Pilgrim Nuclear Power Station. With numerous landing sites for their catch along the western shore of Cape Cod Bay, it is not feasible to monitor the entire local lobster fishery. Instead, we are sampling the trap-catch of a commercial lobsterman in the Pilgrim study area (Figure 1), and we use his catch as an index of the fishery.

Twice a month from May through November, we sample the catch of this lobsterman. To facilitate data collecting and the subsequent analyses, the study area is partitioned into a grid (0.8 km^2 quadrats) on a nautical chart (Figure 2), and the catch is associated with the quadrats as located by LORAN C bearings and/or visual sightings in the field. Data are pooled for reference and surveillance areas. Our analysis included data from 1983-1991. Prior to 1983, we sampled the catch of another lobsterman which differed in fishing power and gear design.

Research Lobster Trap Fishing

Six years ago, we implemented a field research lobster program to augment our commercial study. We are able to assess more accurately the impact of the thermal discharge from Pilgrim Station on the local lobster population/fishery. This study has allowed us to control sampling effort in time and space and, in general, to standardize operations. Experimental trap fishing is conducted from June through September in the area of the thermal discharge and at two reference locations in the Pilgrim area using standardized procedures and gear to improve data accuracy and

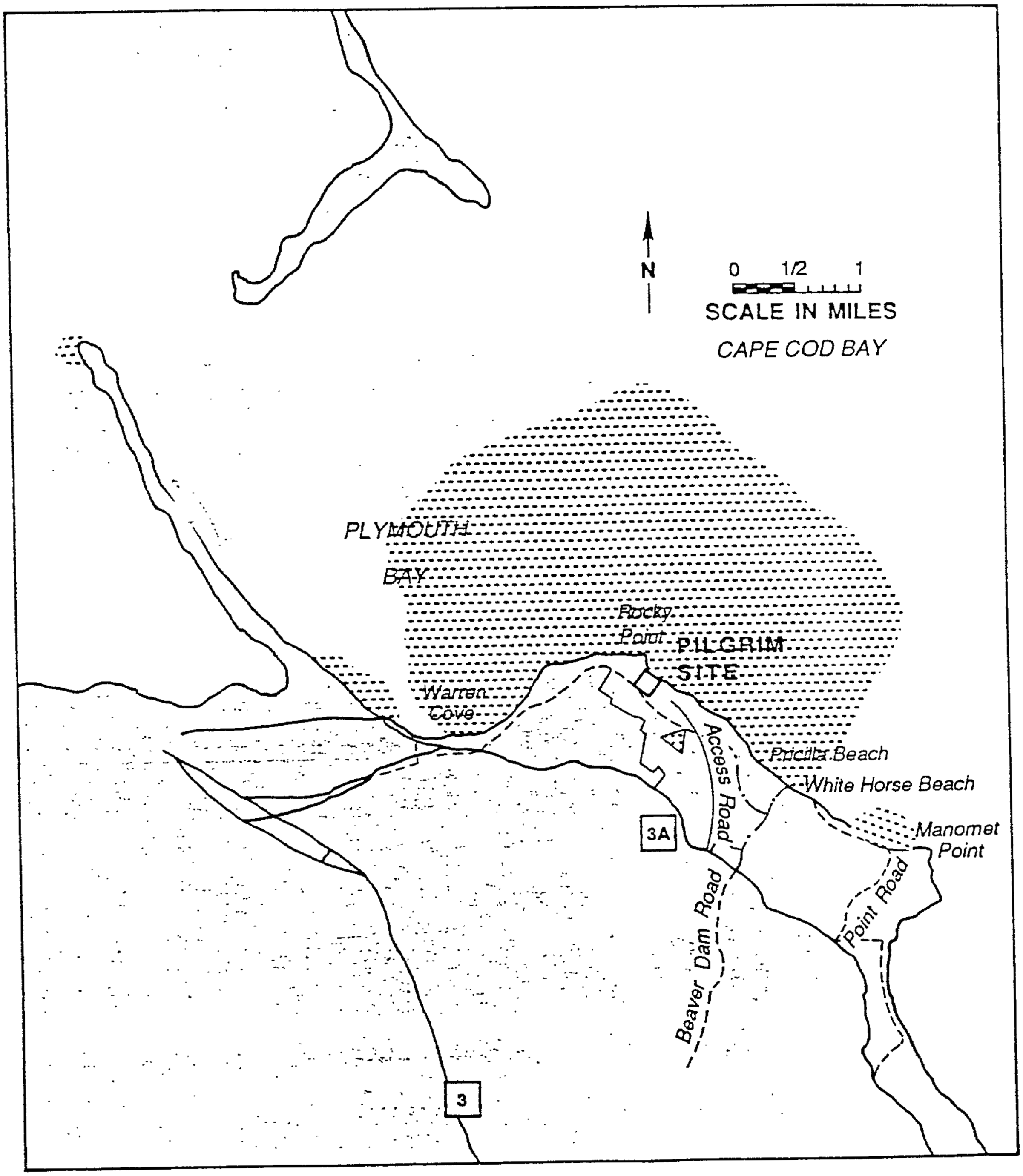

Figure 1. Location of Marine Fisheries sampling areas (hatched) for trawl, gill net, haul seine, lobster, dive, and sportfish surveys in the Pilgrim study area.

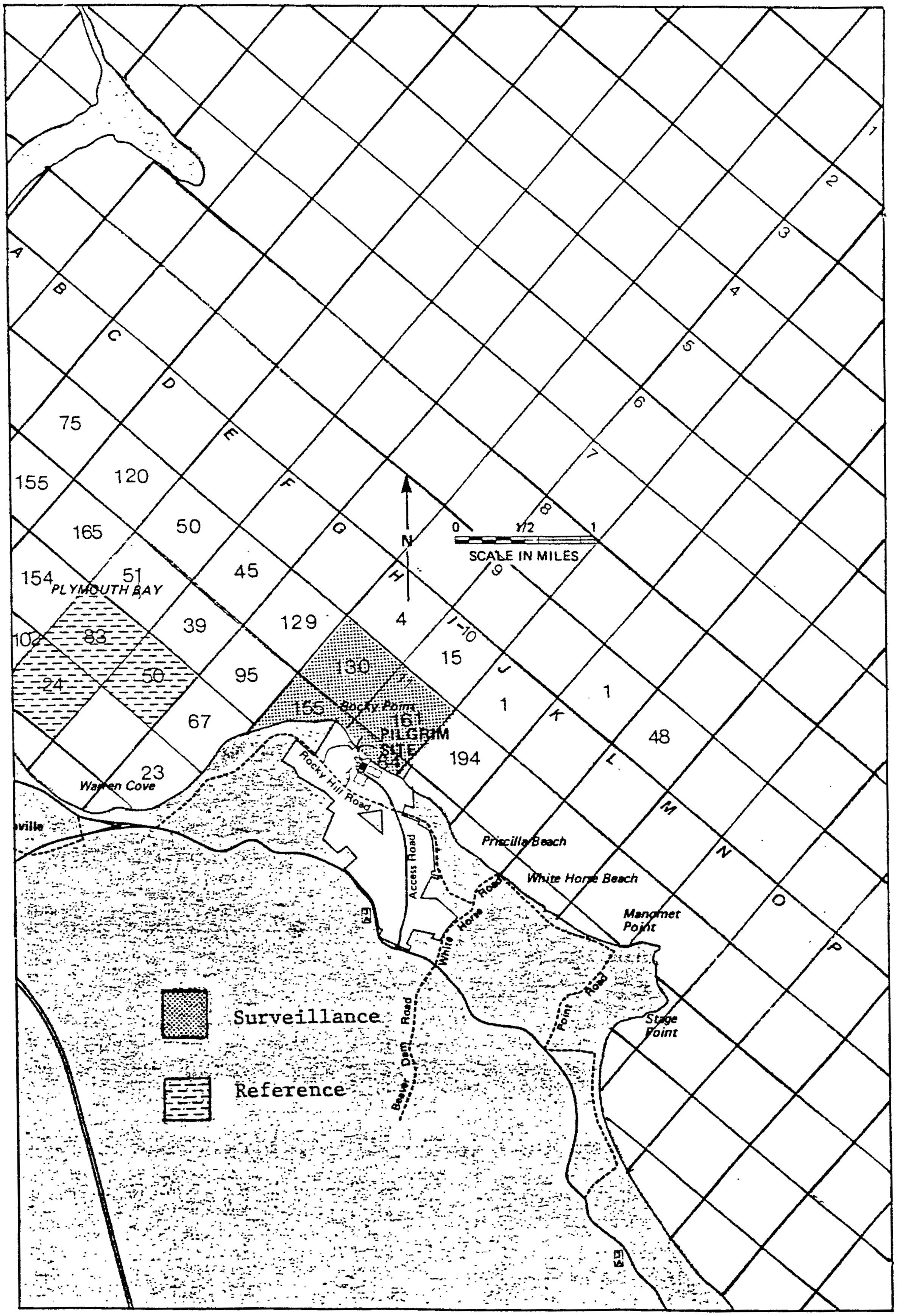

Figure 2. Lobster pot sampling grid for the commercial lobsterman monitored in the Pilgrim Power Plant area [surveillance (H-11, H-12, I-11, and I-12) and reference (E-13, E-14, and F-13) quadrats are shaded] and distribution of his traps sampled in 1991.

precision. Not often are natural populations uniformly distributed in space. Stations are marked with an anchor-buoy arrangement: four (E-H) in the discharge area and six (A-D; I-J) in the two reference areas (see Figure 3 in Section II (Introduction) of Semi-Annual Report No. 39). Randomization was initially applied in the selection of stations within an area.

Standard commercial, vinyl-coated wire lobster traps (91 cm x 51 cm x 30 cm) are fished in trawls. Ten trawls, consisting of five traps (spaced 30 m apart) per trawl, provide spatial replicates. One trawl occupied each station. Pots are hauled every other day in the morning, weather permitting. This controls soak time (duration of a set). The data from each sampling day provide replicates over time.

Water temperature is measured at each station on a sampling outing. Traps are emptied of their contents, rebaited, and relocated on station. Only flounder racks are used as an attractant in the pots to standardize the effect of bait type on lobster catchability. For each pot hauled, the lobster are counted, measured, and sexed. They are also examined for missing claws, presence of eggs, shell hardness, and disease and then released in the area of capture. Periodically, a sub-sample of lobster is retained for radiological analysis.

We have three seasons (1986-88) of base-line data collected under essentially unstressed conditions when Pilgrim Station was in a prolonged outage. In 1989, the discharge site was sampled for the first time in this study under the influence of some waste heat and generally stronger current as the power plant gradually increased operational load during the lobster sampling. In 1990, the plant operated at an annual capacity of 72%, with both circulating seawater pumps running from June through September. However, there was a reduction in heat discharged during July and September. In 1991, the plant's thermal capacity was 0% in June and July and only 28% in August during an outage period; Pilgrim operated at 96% thermal capacity in September.

The 1986-1988 outage at the plant provided us with a baseline period, where our work became a uniformity trial of fishing standard commercial traps in a standardized manner in the defined study area. As noted in other baited trap studies (Miller 1990), we anticipated large differences in catch rates over seemingly homogenous bottom type (e.g., the two reference areas). Variance control in any pot study therefore becomes paramount (Miller 1990) - the less statistical noise, the more precise the final impact analysis. Over the course of our research lobster experiment, we have used the same bait, soak time, time of gear haulback and processing, and trap design. The proper pairing of potentially impacted/surveillance areas (with stations randomly selected within) with non-impacted/reference areas was a prime concern. We believe the station pairs selected would reflect natural environmental changes in a similar way.

Bottom Trawling

Groundfish in the nearshore Pilgrim area are sampled via small vessel (6.7 m) bottom trawling, begun in 1981. Four stations are trawled monthly January through March and biweekly April through December during the daytime (See Figure 2 in Section II (Introduction) of Semi-Annual Report No. 39). The surveillance stations are T-3 (Discharge) and T-6 (Intake), and the reference stations are T-1 in Warren Cove and T-4 located northwest of Priscilla Beach. Stations were selected based on available substrate for trawling, water depth, bottom type, and known patterns of the thermal plume. Duplicate 15-minute tows are made at each station using a 9.8 m Wilcox trawl (9.8 m sweep, 7.0 m headrope, of 11.4 cm stretch mesh; and fitted with a 6.4 mm stretch mesh cod-end liner). If a standard tow was not obtained because of interference with lobster gear, catch values are extrapolated using a weighting function.

Standard survey procedures and trawl log sheets are used. Fish are identified, enumerated, measured, and released alive, except for quarterly samples which are retained for radiological analyses. Invertebrates are identified and counted; lobster in addition, are measured as to being legal or sublegal. Water temperatures are collected while sampling at each station.

Observational Diving

The underwater observational program consists of SCUBA dives made at six permanently marked stations by biologist-divers (see Figure 2 in Section II (Introduction) of Semi-Annual Report No. 39). The present sampling stations were selected in 1981. Research dives are made biweekly from May through mid-August, weekly from mid-August until mid-September, and then biweekly through October. During each dive, which occurs at high tide, divers descend to the bottom from off a boat anchored just outside the discharge canal. Each station is occupied consecutively, and visual observations are made of marine life. The emphasis is on identifying, counting, estimating size, and evaluating the general condition and behavior of finfish in the area. Bottom water temperatures are taken with a hand-held thermometer, and visibility estimates made using a Secchi disk.

Gill-Net Sampling

Pelagic and benthi-pelagic fish in the Pilgrim area are sampled by gill net fished parallel to shore at a depth of about three meters (MLW), near a ledge extending north from the mouth of the discharge canal (See Figure 1 in Section II (Introduction) of Semi-Annual Report No.39). The sampling site is partially within the discharge area. Sampling is conducted monthly throughout the year. The sets are standardized with the net being set before sunset and retrieved at sunrise the following day. This takes advantage of the greater sampling efficiency of a gill net (passive gear) after dark.

We employ a sinking monofilament gill net (213.4 m long by 3.0 m deep), which is anchored on station. The net fishes almost the entire water column at low tide. To counter bias in gear selectivity, an experimental net is used, consisting of seven 30.5 m panels of the following stretch mesh sizes: 38 mm, 50 mm, 63 mm, 75 mm, 88 m, 114 mm, and 152 mm, strung end to end. To further reduce bias, the end of the net positioned closest to the discharge canal is reversed on alternate sets. Water temperatures (bottom and surface) are taken at each end of the net when setting and hauling.

Our objectives are to provide systematic collections of finfish for radiological analysis and to obtain data records of relative abundance for dominant finfish species.

Haul Seining

To monitor finfish occurring along the shoreline, i.e., the intertidal and shallow subtidal zones, haul seining has been conducted since 1981. We have sampled biweekly during the daytime at four stations from June-November, when many fishes inhabit the shoreline (see Figure 1 in Section II (Introduction) of Semi-Annual Report No. 39). Winter/early spring sampling was omitted because cold temperatures reduce or occlude fish distribution in shoal waters. Found along the shore are forage species and the juveniles of many important commercial and sport species.

We have conducted standardized beach seining at Stations S-2, S-4, and S-5 using a 45.7 m by 1.8 m haul seine with a 1.8 m^3 bag of 0.48 cm square mesh (twine #63). Sampling is constrained by the greater depth at the surveillance site (Station S-3, Intake); thus a deeper seine (45.7 m by 3.0 m) set from a small powered skiff is used there. Duplicate hauls are made at each station within ± 2 hours of low tide. Surface water temperature and salinity are measured at each station.

For each station, we have endeavored to keep the area (m^2) seined constant to standardize effort within a site over time. Captured fish are identified, enumerated, and up to 50 individuals of each species measured. Unusually large catches are subsampled to reduce mortality, with total catch extrapolated from volume-unit counts. Catch per unit effort (defined as catch per seine haul) has been calculated for numerically dominant species.

Sportfish Survey

The recreational catch at Pilgrim Station's Shorefront area has been monitored from June through August by public relations' personnel at the waterfront. This has allowed us to maintain a database on sportfishing in the Pilgrim area. Daily catch data have been recorded on a questionnaire (Figure 3). We also spot-checked the area for recreational fishing during April, May, and September and October.

Cunner Capture and Tagging

To capture cunner off the power plant, we use weighted baited eel pots constructed of vinyl coated wire with the following dimensions: 30.5 cm x 30.5 cm x 58.4 cm with a 1 cm^2 opening in the mesh of the wire. The bait is frozen fish (pollock, bluefish) and/or crushed blue mussels.

The tag we selected had to be suitable for a relatively small fish (as is the cunner) and had to be visible to divers. We selected the floy t-bar anchor tag (63.5 mm in length) to mark individual fish. The tag is inserted into the dorsal musculature on the left side using a tagging gun (Figure 4). Red-colored tags were used in the discharge area and blue ones in the reference area in 1991.

Interviewer's Initials		Sheet #
	1991 Recreational Fish Survey - PNPS Shorefront	

	Date
	Weather
	Wind Direction and Speed
	Number of Anglers for the Day
	Fishing Locations
	Hours the Shorefront was open and fishing allowed (e.g., 6 am - 5:30 pm)

Species	Total Number Caught for Day
Flounder (Flatfish)	
Striped Bass	
Bluefish	
Cod	
Pollock	
Tautog	
Mackerel	
Cunner (Sea Perch)	
Other	

Comments:

Figure 3. Sportfish survey form used at the Pilgrim Shorefront.

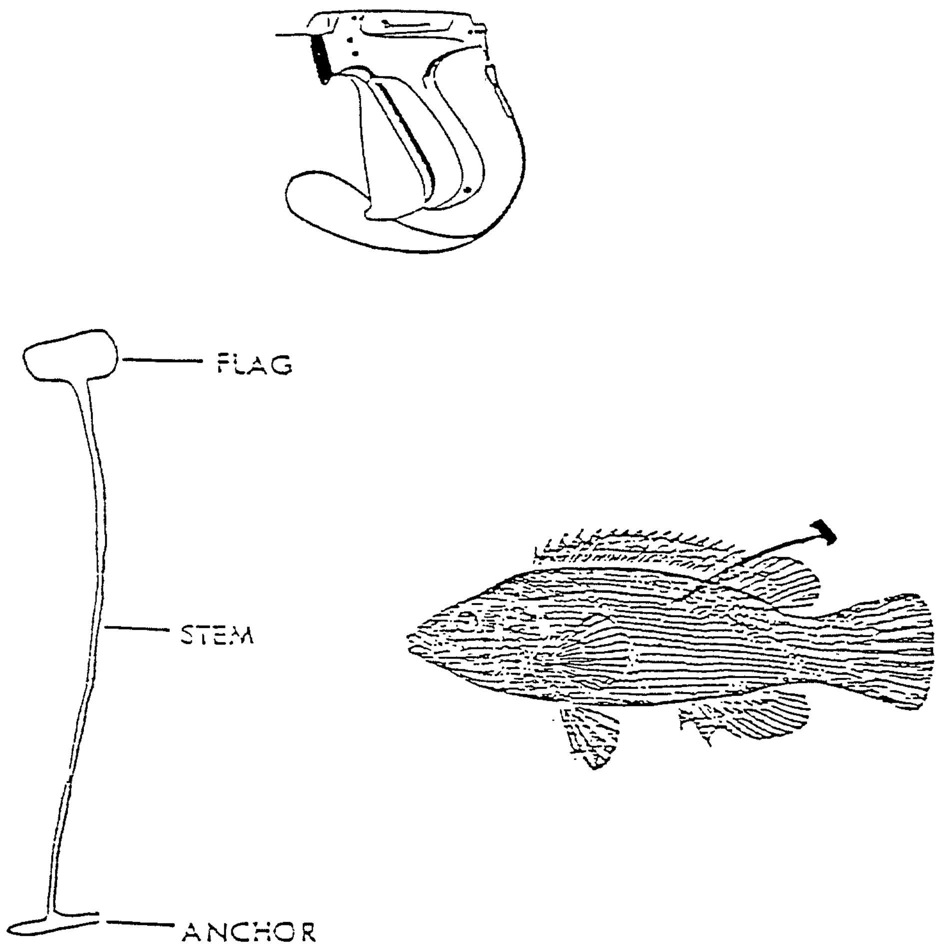

Figure 4. Floy plastic anchor tag and tagging gun used to tag cunner off Pilgrim Station. Location of tag on a tagged cunner is also shown.

IV. RESULTS AND DISCUSSION

A. FISHERIES - LOBSTER

1. Commercial lobster pot-catch fishery

Monitoring the commercial American lobster (*Homarus americanus*) fishery in 1991 in the Pilgrim study area began in May and concluded in October. Lobster catch statistics and biological data (i.e., carapace length - CL, sex, shell hardness) were collected over the six months during 11 sampling trips aboard a commercial lobster boat. Data were obtained on 5,562 lobster taken from 2,432 lobster pot-hauls.

Overall catch per pot of legal - CL ≥82.6 mm - and sublegal lobster from the Pilgrim area was 2.3, while last year's value was 2.5. Sixteen percent (894) of the total catch were legal lobster for an annual catch rate of 0.37 legals per trap-haul, which is 16% lower than last year's rate of 0.44. Relatively low monthly legal catch rates occurred May through July (0.20-0.35), followed by higher rates (0.41-0.63) in August and September (Figure 5). The monthly catch rates of both sublegal and legal lobster generally paralleled that of the pooled lobster catch rates. The annual ratio of sublegal to legal lobster was 5.2:1.

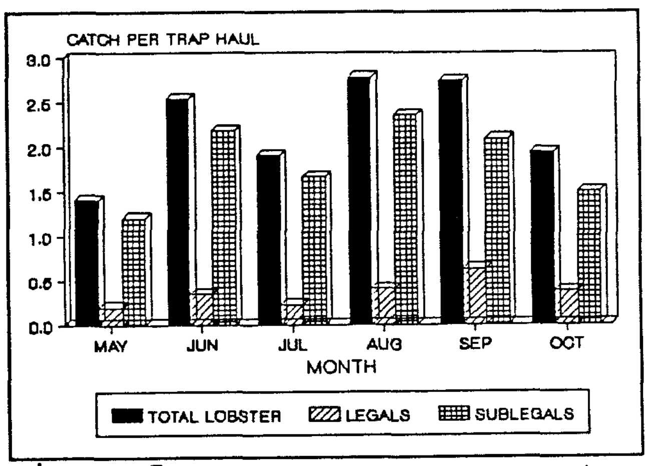

Figure 5. Monthly commercial lobster catch per trap-haul in the Pilgrim area, 1991.

Males comprised 55% of the sampled catch, with monthly sex ratios for June through September favoring males and with May and

October slightly favoring females. There were 109 ovigerous (egg-bearing) females sampled (4.4% of the female catch), of which 76 (3.0% of all females and 70% of all ovigerous females) were sublegal. The overall percentage of ovigerous females was again higher from late summer through early fall (September 6.8% and October 25.2%) as compared to summer (1.7% in June and 0.0% in July). The elevated value in October is higher than usual for this month, and may be an artifact of a relatively small sample size. The seasonality in the incidence of egg-bearing females reflects the two-year reproductive cycle of the American lobster (Aiken and Waddy 1982). Sexually mature females generally mate after the summer molt, but it is not until fall of the following year that they extrude their fertilized eggs which are carried externally throughout the winter, hatching from late spring into the summer.

2. <u>Research Lobster Trap Fishing</u>

We trapped lobster from June through September 1991 in the environs of Pilgrim Station. This year was the sixth of our research trap fishing. We completed 53 sampling trips on a contracted commercial lobster boat. Effort consisted of 2,650 trap-hauls, while sample size totaled 9,682 lobster of which 10.0% were legal-sized. For the past two years, the minimum legal size for lobster retention in Massachusetts has remained at $\geq$ 82.55 mm (3.25 inches) carapace length (CL), after having undergone a gauge increase in 1988 and 1989. These changes in legal size were not accompanied by an increase in the size of the escape vent in each of our traps. This contributed directly to increased catches of sublegal lobster as compared to legals and is reflected in the annual catch ratio of sublegal to legal which was 5.8:1 in 1988, 6.6:1 in 1989, 8.1:1 in 1990, and 9.0:1 in 1991. Enhanced recruitment of sublegals into the pre-recruit and legal size range most likely was the reason, as the Cape Cod Bay lobster resource appears to be over-exploited (Estrella and Cadrin 1989). Ennis (1983) found that with lobster exploitation rates as high as 94% in Comfort Cove of Notre Dame Bay, Newfoundland, recruitment via the molt is the main factor influencing the abundance of legal-sized lobster in a given year.

The number of lobster of all sizes captured over a two-day set ranged from 0 to 12 per trap-haul, with legal catch ranging from 0 to 5 and sublegal, 0 to 12. In 4% of the hauled traps, no lobster were taken. The overall seasonal (June-September) mean catch-per-trap-haul (CTH) in the study area of lobster (pooled for size and sex) has increased, ranging from 1.2 in 1986 to 3.7 in 1990 and 1991. Monthly catch rates as catch per trap-haul per set-over day, CTHSOD, of legal and CTH of sublegal lobster in the study area for 1991 are plotted in Figures 6 and 7, respectively. The legal catch rates generally peaked in August and September. Sublegal catch rates were generally highest in July or August.

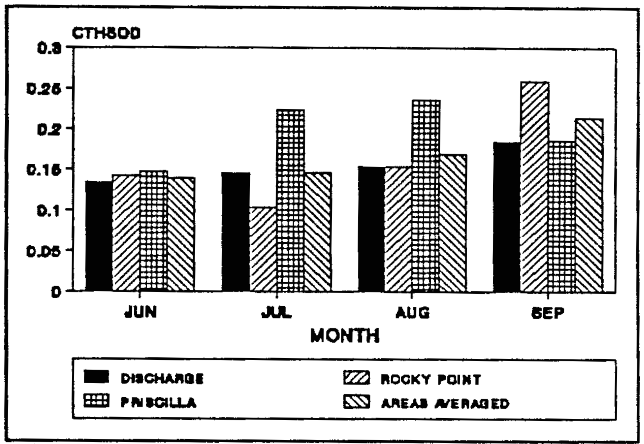

Figure 6. Monthly legal lobster catch rates (CTHSOD) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1991.

Males again outnumbered females in the research trap catches, comprising 57% of the total. Conversely, females have typically outnumbered males in past commercial catches made in the slightly deeper waters of western Cape Cod Bay (Kelly et al. 1987;

Lawton et al. 1990). However, this year, males predominated (55%) in the commercial catch. A preponderance of males in shoal water pot-catches also was reported by Briggs and Muschacke (1979) in Long Island Sound.

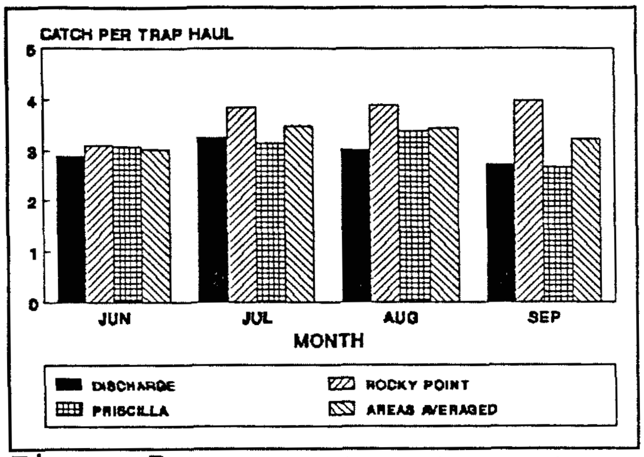

Figure 7. Monthly sublegal lobster catch rates (CTH) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1991.

There were 61 egg-bearing (ovigerous) females sampled which represents 1.5% of the research catch of females. The percent of females ovigerous was 1.2% in last year's research catch. Over the years, this value has typically hovered near 1% in commercial catches from western Cape Cod Bay (4.4% in 1991, see Volume 2).

Culls (lobster with missing and/or regenerating claw(s)) captured during research fishing in 1991 comprised 29% of the catch. The cull rate in 1990 was similar and somewhat higher than in 1989 (27%) and in 1988 (23%). In general, the cull rate obtained by sampling commercial catches has increased in the Pilgrim area during the past decade, concomitant with an expansion in commercial and recreational lobstering efforts.

The commercial lobster traps employed in this study each contain a rectangular escape vent (44.5 mm x 152.4 mm) and are designed to retain legal-sized lobster; however, sublegals are captured to an extent. The size range (CL) of lobster sampled the summer of 1991 was 33 mm to 114 mm. The overall mean size was 75.3 mm, which is less than 1 mm smaller than the average for 1990. Sublegals averaged 73.9 mm CL, and legals, 87.2 mm CL.

Size-catch distributions were plotted for 1991 data (Figure 8) and for all six years (1986-1991) together (Figure 9). The length-frequency histograms display effects of lobster availability, vulnerability, and fishing mortality. The general stepwise increase in catch between 50 and 75 mm CL suggests that between those measurements, lobster are increasingly vulnerable to retention in the traps. The mode was at the pre-recruit size of 79 mm CL. Reduced catches of lobster < 73 mm are most likely influenced by gear design (vent escapement). The lower numbers of lobster at legal size and greater reflect high fishing mortality via intensive commercial and recreational lobster fisheries in the Pilgrim Station area.

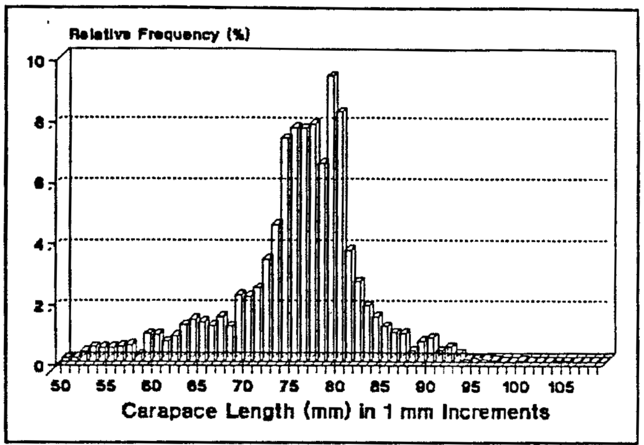

Figure 8. Size distribution of lobster captured in the research trap study off Pilgrim Station in 1991.

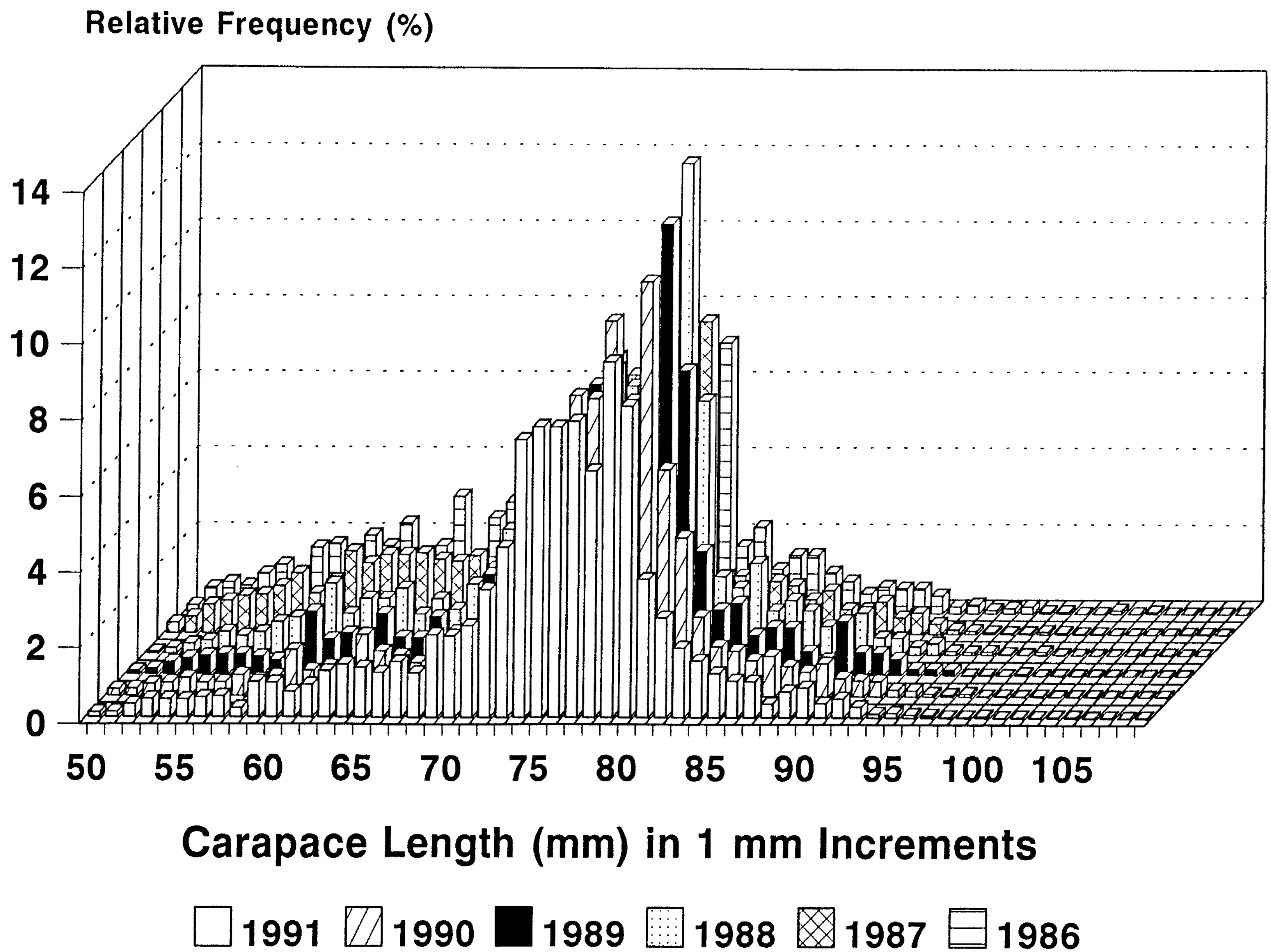

Figure 9. Size distribution of lobster captured in the research trap study off Pilgrim Station from 1986 to 1991.

B. FISHERIES - FINFISH

A species check list of fish observed or collected by all gear types in the Pilgrim area in 1991, complete with scientific names (Robins et al. 1991), is found in Table 1.

Table 1. Checklist of finfish species (following classification of Robins et al. 1991) collected or observed in the adjacent marine waters off Pilgrim Station, 1991.

Class: Elasmobranchiomorphi
- Order: Lamniformes
  - Family: Carcharinidae - requiem sharks
    - *Mustelus canis* (Mitchill) - smooth dogfish
- Order: Squaliformes
  - Family: Squalidae - dogfish sharks
    - *Squalus acanthias* Linnaeus - spiny dogfish
- Order: Rajiformes
  - Family: Rajidae - skates
    - *Raja erinacea* (Mitchill) - little skate

Class: Osteichthyes
- Order: Clupeiformes
  - Family: Clupeidae - herrings
    - *Alosa aestivalis* (Mitchill) - blueback herring
    - *Alosa pseudoharengus* (Wilson) - alewife
    - *Brevoortia tyrannus* (Latrobe) - Atlantic menhaden
    - *Clupea harengus* Linnaeus - Atlantic herring
  - Family: Engraulidae - anchovies
    - *Anchoa mitchilli* (Valenciennes) - bay anchovy
- Order: Salmoniformes
  - Family: Osmeridae - smelts
    - *Osmerus mordax* (Mitchill) - rainbow smelt
- Order: Gadiformes
  - Family: Gadidae - codfishes
    - *Gadus morhua* Linnaeus - Atlantic cod
    - *Microgadus tomcod* (Walbaum) - Atlantic tomcod
    - *Pollachius virens* (Linneaus) - pollock
    - *Urophycis tenuis* (Mitchill) - white hake
    - *Urophycis chuss* (Walbaum) - red hake
- Order: Atheriniformes
  - Family: Cyprinodontidae - killifishes
    - *Fundulus majalis* (Walbaum) - striped killifish
    - *Fundulus heteroclitus* (Linnaeus) - mummichog
  - Family: Atherinidae - silversides
    - *Menidia menidia* (Linnaeus) - Atlantic silverside
- Order: Gasterosteiformes
  - Family: Gasterosteidae - sticklebacks
    - *Gasterosteus aculeatus* Linneaus - threespine stickleback
    - *Apeltes quadracus* (Mitchill) - fourspine stickleback
  - Family: Syngnathidae - pipefishes and seahorses
    - *Syngnathus fuscus* Storer - northern pipefish

Order Scorpaeniformes
Family: Triglidae - searobins
Prionotus carolinus (Linnaeus) - nothern searobin
Prionotus evolans (Linnaeus) - striped searobin

Family: Cottidae - sculpins
Hemitripterus americanus (Gmelin) - sea raven
Myoxocephalus aenaeus (Mitchill) - grubby
Myoxocephalus octodecemspinosus (Mitchill) - longhorn sculpin
Myoxocephalus scorpius (Linnaeus) - shorthorn sculpin

Family: Cyclopteridae - lumpfishes and snailfishes
Cyclopterus lumpus Linnaeus - lumpfish

Order: Perciformes
Family: Percichthyidae - temperate basses
Morone saxatilis (Walbaum) - striped bass

Family: Serranidae - sea basses
Centropristis striata (Linnaeus) - black sea bass

Family: Pomatomidae - bluefishes
Pomatomus saltatrix (Linnaeus) - bluefish

Family: Carangidae - jacks
Seriola zonata (Mitchill) - banded rudderfish
Decapterus macarellus (Cuvier) - mackerel scad

Family: Sciaenidae - drums
Menticirrhus saxatilis (Bloch and Schneider) - northern kingfish
Leiostomus xanthurus Lacepede - spot

Family: Sparidae - porgies
Stenotomus chrysops (Linnaeus) - scup

Family: Mugilidae - mullets
Mugil curema Valenciennes - white mullet

Family: Labridae - wrasses
Tautoga onitis (Linnaeus) - tautog
Tautogolabrus adspersus (Walbaum) - cunner

Family: Zoarcidae - eelpouts
Macrozoarces americanus (Schneider) - ocean pout

Family: Pholidae - gunnels
Pholis gunnellus (Linnaeus) - rock gunnel

Family: Ammodytidae - sand lances
Ammodytes americanus DeKay - American sand lance

Family: Scombridae - mackerels
Scomber scombrus Linnaeus - Atlantic mackerel

Family: Stromateidae - butterfishes
Peprilus triacanthus (Peck) - butterfish

Order: Pleuronectiformes
Family: Bothidae - lefteye flounders
Scophthalmus aquosus (Mitchill) - windowpane

Family: Pleuronectidae - righteye flounders
Pleuronectes ferrugineus (Storer) - yellowtail flounder
Pleuronectes americanus Walbaum - winter flounder

Order: Tetraodontiformes
Family: Tetraodontidae - puffers
Sphoeroides maculatus (Bloch and Schneider) - northern puffer

1. Nearshore Groundfish

The catch from 130 bottom trawls in the study area in 1991 totaled 503 fish, representing 21 species (Table 2). Five species - Atlantic herring, winter flounder, little skate, Atlantic cod, and windowpane - comprised 91% of the total. Overall mean catch per tow (a measure of catch per unit effort, or CPUE) calculated from pooled species and station data was 3.9, identical to the 1990 value (Figure 10). There has been a downward trend in our trawl

Table 2. Expanded catch[1] and percent composition of groundfish captured by bottom trawling at four stations in the vicinity of Pilgrim Station, January to December, 1991.

Species	1 Warren Cove	3 Pilgrim Discharge	4 Priscilla Beach	6 Pilgrim Intake	Totals	Percent of total catch
Atlantic herring	0.0	2.0	297.0	1.0	300.0	59.6
Winter flounder	0.0	15.0	40.0	17.8	72.8	14.5
Little skate	1.0	11.0	11.0	22.9	45.9	9.1
Atlantic cod	0.0	8.0	4.0	8.0	20.0	4.0
Windowpane	0.0	8.0	8.0	3.0	19.0	3.8
Atlantic silverside	0.0	1.0	7.0	4.5	12.5	2.5
Butterfish	0.0	0.0	5.0	0.0	5.0	1.0
Rock gunnel	1.0	0.0	4.0	0.0	5.0	1.0
Other species[2]	1.0	6.4	9.0	6.6	23.0	4.6
Total fish	3.0	51.4	385.0	63.8	503.2	
Number of tows	35	34	37	24	130	
Catch per tow	0.1	1.5	10.4	2.7	3.9	
Percent of catch	0.6	10.2	76.5	12.7		
Number of species	3	12	14	10	21	

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
[2]Represents pooled totals from 13 species of low catch abundance.
Shaded columns are data collected at surveillance stations.

catches since 1987. Low numbers of fish make detection of impact from the operation of Pilgrim Station difficult, especially to separate plant impact from natural variation. A review of stock assessment work by the National Marine Fisheries Service (NMFS) Northeast Fisheries Center (NEFC 1991) points to the generally depressed state of groundfish abundance in the Northwest Atlantic.

Catch rates also were calculated for individual stations, the highest being found at Priscilla Beach (Station 4) with a mean CPUE (pooled species) of 10.4 fish per tow. It should be noted, however, that the magnitude of this index was greatly influenced by the capture of nearly 300 juvenile Atlantic herring during a single tow made there in the spring. The occurrence of this species in our bottom trawl catches is rare because this species is pelagic. Exclusion of these data from the calculation yields a mean catch rate of 2.4 at this station. The Intake (Station 6) and the Discharge (Station 3) catch rates were 2.7 and 1.5, respectively, while that in Warren Cove (Station 1) was 0.1.

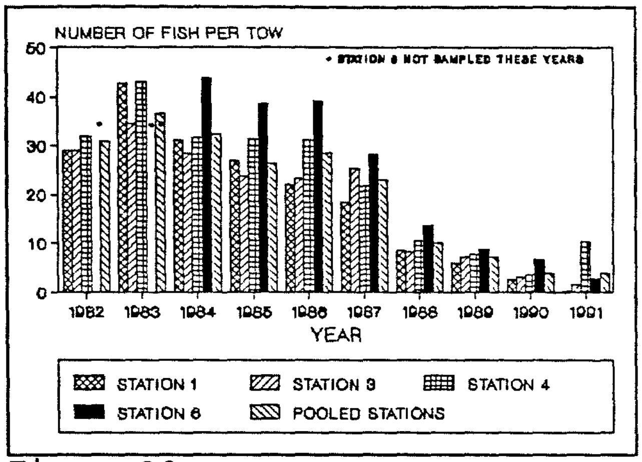

Figure 10. Mean annual catch per tow by station for pooled species trawled in the environs of Pilgrim Nuclear Power Station, 1982-1991.

Winter flounder

Ranked second in trawl catch (14.5% - all stations pooled), winter flounder was numerically dominant at Station 4. Overall CPUE declined for the fifth consecutive year to 0.6 (Figure 11). The NMFS reported that winter flounder abundance in the Gulf of Maine declined overall in 1990 to its

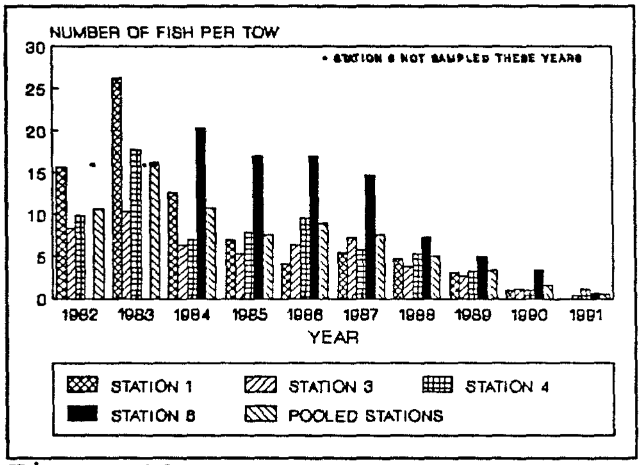

Figure 11. Mean annual catch per tow by station for winter flounder trawled in the vicinity of Pilgrim Station, 1982-1991.

lowest level of the last 10 years (NEFC 1991). Off Priscilla Beach, the winter flounder catch ranked first, with an annual mean CPUE of 1.1 (Table 3). Annual mean CPUE in the Intake dropped from 3.4 (1990) to 0.7, and in the Discharge from 1.2 (1990) to 0.4. No winter flounder were trawled in Warren Cove.

A comparison of the annual mean size of winter flounder captured at each station (Table 3) revealed little variation between stations in 1991.

Table 3. Bottom trawl catch data[1] for dominant groundfish in the vicinity of Pilgrim Station, January to December, 1991.

Station	Winter flounder	Little skate	Windowpane
1			
Mean catch per tow	0.0	0.03	0.0
Mean size (cm)	-	44	-
Size range (cm)	-	-	-
3			
Mean catch per tow	0.4	0.3	0.2
Mean size (cm)	28	35	25
Size range (cm)	12-39	24-48	16-37
4			
Mean catch per tow	1.1	0.3	0.2
Mean size (cm)	26	36	25
Size range (cm)	9-41	24-48	14-31
6			
Mean catch per tow	0.7	1.0	0.1
Mean size (cm)	27	34	23
Size range (cm)	11-38	20-55	17-28

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
Shaded rows are data collected at surveillance stations.

Little skate

Little skate comprised 9% of the overall trawl catch. Mean annual catch per tow for all stations pooled was 0.4 (Figure 12), down 50% from 0.8 in 1990 and the lowest value recorded for this species in our study. A comparison with Gulf of Maine catch rates was not possible; the NMFS does not differentiate between catches of little skate and winter skate (*Raja ocellata*). The highest annual station catch rate (1.0 little skate per tow) was recorded in the Intake Embayment, followed both by Priscilla Beach and the Discharge at 0.3 (Table 3). The lowest relative abundance was in Warren Cove with 0.03 fish per tow. Comparing data over the years (Figure 12) reveals a marked drop in relative abundance occurred at all stations in 1988, with the stock remaining depressed thereafter.

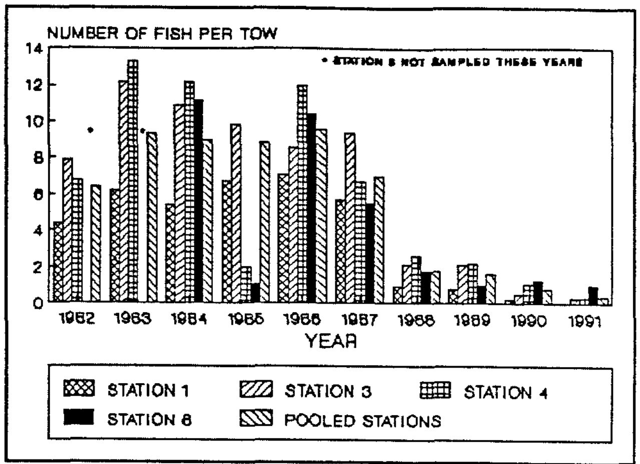

Figure 12. Mean annual catch per tow by station for little skate trawled in the vicinity of Pilgrim Station, 1982-1991.

<u>Windowpane</u>

Windowpane ranked fifth in overall trawl catch (3.8% - pooled data). Mean annual CPUE for all stations combined was 0.1, down from a value of 0.7 in 1990 (Figure 13). Following a sharp decline in 1988, relative abundance has remained at a depressed level. A very thin-bodied fish, windowpane were formerly not exploited commercially. They have become more sought after in the absence or low abundance of more desirable species. The windowpane has not been a target species for stock assessment, and little or no NMFS data were available.

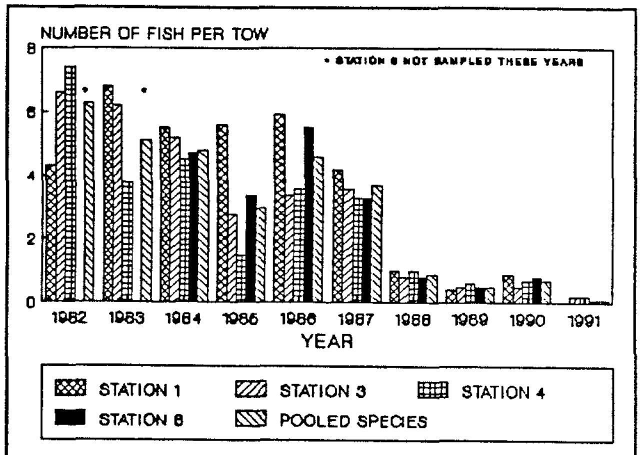

Figure 13. Mean annual catch per tow by station for windowpane trawled in the vicinity of Pilgrim Station, 1982-1991.

Among the four sampling stations, annual CPUE for windowpane was fairly consistent, ranging from 0.1-0.2 fish per tow.

Other Species

Comprising 13% of the total trawl catch, the remaining 17 species were not captured in abundant numbers. Overall catch rate for this group (pooled species and stations) was 0.5 fish.

2. Pelagic and benthi-pelagic fishes

Monthly gill-net catches in 1991 yielded 20 finfish species numbering 1012 fish. The top 10 species are listed in Table 4. No set was made in December because of inclement weather.

Table 4. Catch in number and percent composition of the top 10 fish species sampled by gill net (7 panels of 3.8-15.2 cm mesh) in the immediate vicinity of Pilgrim Station, January-December 1991.

	Species	Number	Percent of Total Catch
1.	Pollock	417	41.2
2.	Atlantic herring	233	23.0
3.	Cunner	64	6.3
4.	Tautog	53	5.2
5.	Bluefish	51	5.0
6.	Striped bass	48	4.7
7.	Smooth dogfish	43	4.2
8.	Scup	24	2.4
9.	Silver hake	16	1.6
10.	Northern searobin	13	1.3
	Total 10 Species	962	95.1

The annual mean catch rate (catch per standard set) for pooled species by gill net (5 panels of 3.8 - 8.9 cm mesh) increased slightly to 82.3 fish per set from last year's all-time low of 68.8 fish per set (Figure 14). Catches of pollock and Atlantic herring, the two dominant species in gill-net catches over the years, increased in 1991 and contributed to the higher overall catch rate.

Pollock ranked first at 41% of the catch, and Atlantic herring second at 23%. Cunner (6.3% of the catch) regained its traditional third place position in the hierarchy of gill-net catch and was followed by tautog at 5% of the catch. The first three species consistently have dominated gill-net catches since 1971, with few exceptions.

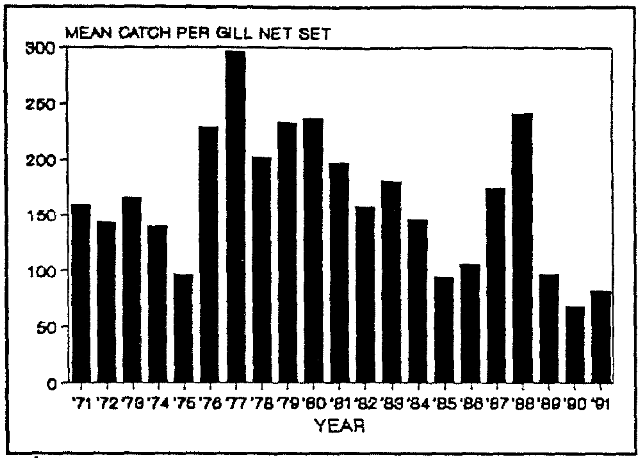

Figure 14. Indices of relative abundance (CPUE) for pooled finfish species captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1991.

Pollock

Pollock were caught primarily from May through November, with the greatest quantity in June. The five-panel catch rate for pollock increased in 1991, yet remains at a depressed level relative to the entire 1971-1991 dataset (Figure 15). This long-term time series of annual relative pollock abundances reveals a wide range in catch rates from a low of about 20 pollock per gill-net set in 1975 and 1990 to a high of nearly 140 in 1977 and 1980.

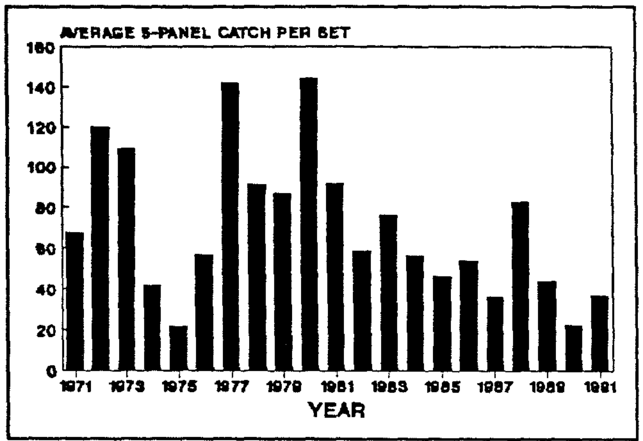

Figure 15. Indices of relative abundance (CPUE) for pollock captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1991.

Atlantic herring

The great majority of the Atlantic herring caught this year were obtained in November. The catch rate for Atlantic herring increased slightly towards the 1989 value from the near record low level of 1990 (Figure 16).

Overall, the catches of herring have fluctuated as greatly as any fish species sampled by the gill net. This species was at its lowest point in abundance in the Pilgrim area in 1985 but reached a zenith in 1988.

Cunner

Cunner were caught every month from April through October. The relative abundance of cunner in the Pilgrim area has remained low since 1985, with this year's catch rate being the second lowest of the 20-year time series, portraying a slight increase from last year's value (Figure 17).

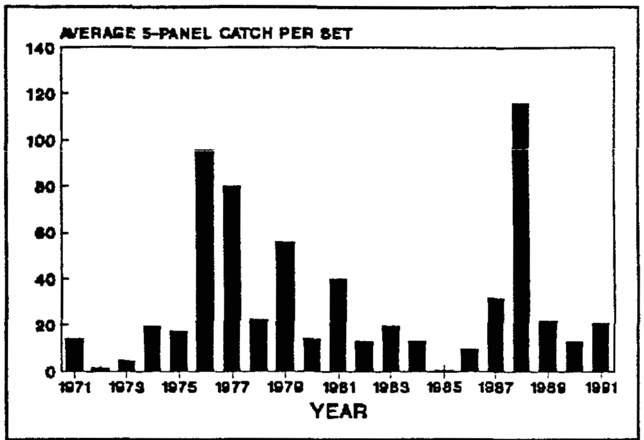

Figure 16. Indices of relative abundance (CPUE) for Atlantic herring captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1991.

Other Species

The catch rate for bluefish increased substantially from last year, while tautog, striped bass, Atlantic menhaden, and Atlantic mackerel decreased in relative abundance. No Atlantic cod were caught this year.

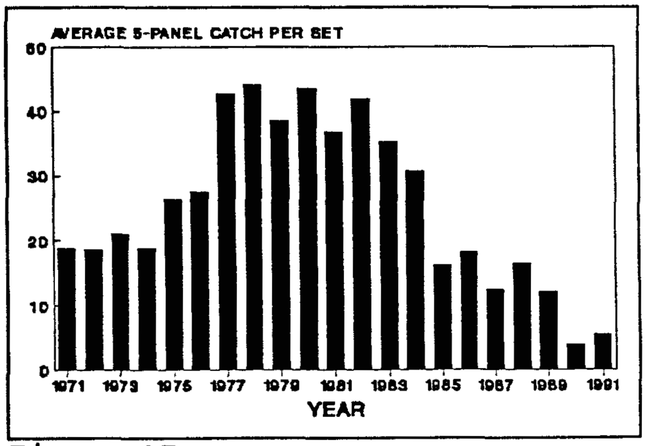

Figure 17. Indices of relative abundance (CPUE) for cunner captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1991.

Striped bass and bluefish have an affinity for the thermal effluent at Pilgrim Station (Lawton et al. 1987). Their numbers (reflected in our gill-net abundance indices) are generally low in the Pilgrim area when the power plant is not fully operational. Pilgrim Station decreased its overall annual operational capacity, and thermal component, from 72% in 1990 to 58% in 1991, and with that, gill net catch rates rose from 2.5 to 4.3 fish per set for bluefish but fell from 7.1 to 2.8 for striped bass.

3. Shore-zone Fishes

A sum of 56,566 finfish comprising 27 species was seined from June to October, 1991 along the Plymouth shoreline (Table 5). No sampling was conducted in November because of a severe five-day northeast storm in late October that caused extensive beach erosion at all sampling sites and damage to access roads. Water temperature and salinity measured during sampling operations ranged from 12°C to 20°C ($\bar{X}$ = 16.6°C) and 30 0/00 to 33 0/00 ($\bar{X}$ = 31.1 0/00), respectively. Three fish species comprised 97% of the total seine catch - Atlantic silverside (46%), Atlantic herring (41%), and sand lance spp.(10%). The mean catch per standard seine haul, pooling stations and species, rose from 254.4 in 1990 to 912.4 in 1991 or about a 3.5-fold increase in catch rate.

Table 5. Shore-zone fishes captured by haul seine in the vicinity of Pilgrim Nuclear Power Station, June to October, 1991.

	Station						
Species	Warren Cove	Pilgrim Intake[1]	Manomet Point	Long Point	Total	Percent Total	Catch Rate
Atlantic silverside	2,398	674	1,030	22,053	26,155	46	421.8
Atlantic herring	5	22,898	0	7	22,910	41	396.6
Sand Lance spp.	5,077	320	8	5	5,410	10	87.3
Other species[2]	133	204	381	372	2,091	3	33.7
Total	7,613	24,096	1,419	22,437	56,566		
Number of sets	18	17	9	18	62		
Catch per set	422.9	1,417.4	157.7	1,302.1	912.4		
Number of species	16	17	6	22	27		
Percent of total catch	14	43	3	40	100		

[1] 45.7 m x 3.0 m seine; other sites sampled with 45.7 m x 1.5 m seine.
[2] Represents pooled total for species of lower abundance.
Shaded column is data from surveillance station.

Large increases in the catches of the Atlantic silverside, Atlantic herring, and sand lance brought about the overall increase in catch rate for the study area in 1991. Catches of juvenile river herring (majority were blueback herring) and Atlantic menhaden, and both juvenile and adult northern pipefish also increased from last year. Catch rates (pooled species) increased at three of the stations and remained about the same at the fourth (Figure 18).

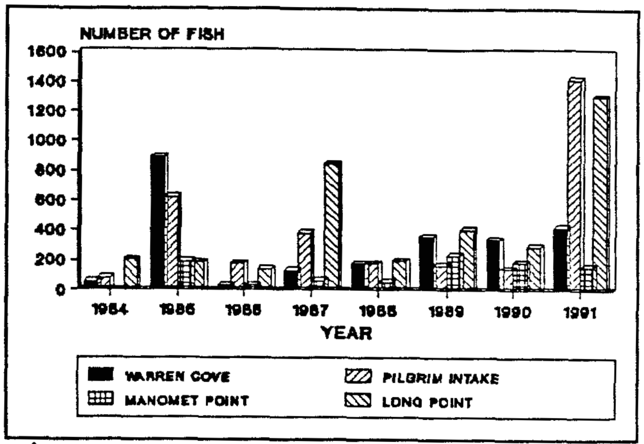

Figure 18. Average catch per seine set of shore-zone fish (pooled species) in the vicinity of Pilgrim Station from 1984 to 1991.

The seine catch by station was highest overall in the Pilgrim Intake, where 43% of the total was obtained, followed by Long Point (40%) (Table 5). The former was a direct result of the unusually large catch of juvenile Atlantic herring made there. The overall catch rate in the Intake increased 10-fold from last year and was the highest of the entire study (Figure 18). The catch rate at Long Point increased 4.5-fold from last year and was the highest value obtained at this station during the entire study.

Atlantic Silverside

The Atlantic silverside ranked first in number of fish captured, as it has every year of seining operations. This species accounted for 46% of the fish seined in 1991. Of the silverside catch, 84% was obtained at Long Point. Low silverside abundance in June in the Pilgrim area was followed by good catches of both juveniles and adults in July. Dominating all catches from July through October, abundance peaked in September. Their overall catch rate (pooled station data) almost doubled from last year.

Atlantic Herring and Sand Lance

Ranking second in seine catch, Atlantic herring were captured in greatest numbers (95%) in Pilgrim's Intake, where a large school of juvenile sea herring resided in early summer. The highest catch, by far, occurred in June.

The catch rate of sand lance increased about 10-fold from 1990. Ninety-four percent of their catch came from Warren Cove.

Diversity - Spatial and Temporal

The highest cumulative number of species (22) was seined at Long Point in 1991. As to monthly totals, the highest number of species (18) was captured in July, August, and September. Of the 27 species seined overall, only 5 were taken at all 4 sampling sites, while 8 were collected at single sites. Of the latter, five species were seined exclusively at Long Point and two in the Intake.

Pilgrim Intake and Long Point shared the most species in common (14) and had the highest catches in number of fish. Both locations are generally protected from heavy surf and possess cover that includes vegetation. This provides suitable habitat for small fish. Conversely, Manomet Point and Warren Cove have sparse cover and are subject to heavy surf. The least populated areas are generally devoid of vegetation, where protection is lacking and food is a limiting factor. Over the years, we consistently have collected more species in the Intake and at Long Point.

The overall seine catch (number of fish) at Warren Cove was dominated by sand lance (67% of the Station total) and Atlantic silverside (31%). Atlantic herring comprised 95% of the catch in the Intake. The highest catch of juvenile winter flounder was recorded in the Intake (72% of the study area total). At Manomet Point, 73% of the catch were silversides and 26%, Atlantic menhaden (juveniles). The largest catch of menhaden was obtained at Manomet Point (79% of the study area total). The catch at Long Point was numerically dominated by Atlantic silversides (94% of the station total). At this site, we recorded the highest catches of Atlantic tomcod (100% of the total), cunner (97%), river herring (97%), silversides (84%), and northern pipefish (82%).

As to temporal changes in catch composition, June's catch was dominated by Atlantic herring, comprising 93% of the month's total. In July, Atlantic silversides (53% of the monthly total) and sand lance (40%) predominated. Silversides led all catches in August (88% of total), September (98%), and October (92%). River herring (mostly blueback herring) also surged in August.

4. Underwater Finfish Observations

Observational diving began in early May, with a total of 13 dives made through mid-October. Over 1,900 fish, comprising 8 species (Table 6), were observed at the sampling stations (See Figure 2 in Section II (Introduction) of Semi-Annual Report #39). Invertebrates noted included the blue mussel (*Mytilus edulis*), lobster, starfish (*Asterias spp.*), and rock crab (*Cancer irroratus*).

Estimates of lateral visibility (obtained with a diver-held secchi disk and metered line) ranged from 1.5-9 m (average 4.6 m), depending on sea condition and incident light. In an attempt to determine the degree of influence of visibility as a controlling factor in diver observations, we plotted mean annual fish per dive values against average visibility for the years 1981 to 1991. No relationship was discernable (e.g., in 1987, visibility averaged 6.3 m with sightings of 41 fish per dive, whereas in 1984, visibility averaged 3.7 m and divers observed nearly 200 fish per dive).

Table 6. Abundance and distribution of finfish species recorded during underwater observations, May to October, 1991.

Species	Number observed by divers	Percent of total	Station where most abundant
Cunner	1,219	63.7	D_1
Striped bass	255	13.3	D_2
Bluefish	203	10.6	D_2
Tautog	191	10.0	D_2
Other*	47	2.4	
Total 8 species	1,915		

* Pollock, Rock gunnel, Winter flounder, and Grubby

The total number of fish recorded in 1991 (1,915) was 25% lower than in 1990 (2,563 fish), due primarily to decreased sightings of tautog, striped bass, and bluefish. Using number of fish sighted per dive as an index of relative abundance, data from 1981 through 1991 are plotted (Figure 19). In 1991, project divers reported an average of 147 fish per dive, a 20% decrease from 1990 (183 fish per dive), but still substantially higher than that recorded from 1985 to 1989. As shown in Figure 19, more fish were observed in the discharge area

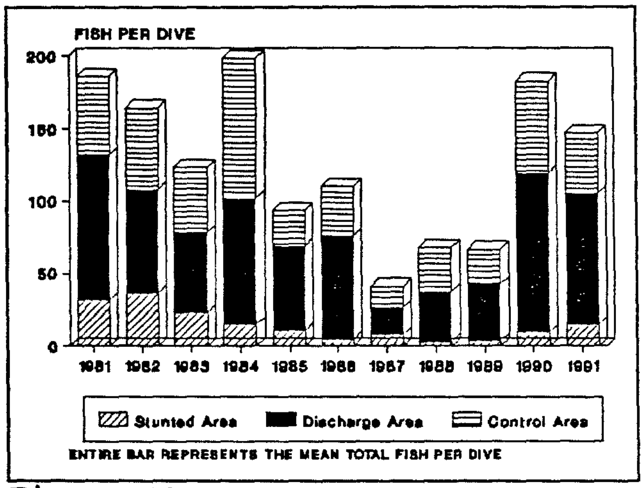

Figure 19. Indices of relative abundance (fish per dive) for all species (pooled) observed by divers at Pilgrim Station, 1981-1991.

(61%) than in the control (28%) and stunted (10%) areas.

Cunner

Occurring at all stations, cunner was the finfish species observed in greatest numbers by project divers, comprising 64% of all sightings (Table 6). Cunner were equally distributed in diver counts between the discharge (43.6%) and control (43.6%) areas, with the remaining 12.7 % found in the stunted area. A cunner per dive index of 94 was similar to that noted in 1990 (98). A plot of cunner per dive data (Figure 20) for the entire study period reveals the 1991 index to be on a par with pre-1984 levels.

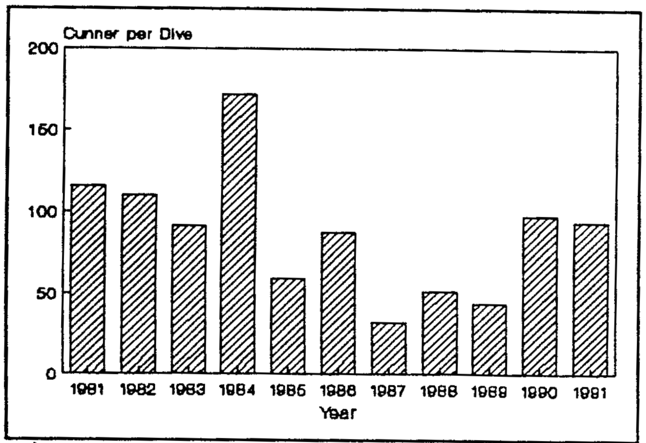

Figure 20. Indices of relative abundance (fish per dive) for cunner observed by divers at Pilgrim Station, 1981-1991.

Examination of individual length estimates made by project divers revealed that far fewer small cunner (2-3 cm) were sighted in 1991 (27% of the total observed) than in 1990 (74%). This is most likely related to year-class strength.

Striped Bass and Bluefish

Striped bass and bluefish ranked second and third, respectively, in our 1991 diver observations (Table 6). Indices of 19.6 fish per dive for striped bass and 15.6 fish for bluefish are the second highest recorded in the diving study. Local occurrence and abundance off Pilgrim Station of both species can be strongly affected by year-class strength and fishing mortality. Commonly angled from the discharge jetties, both species were sighted by divers almost exclusively at Station D_2, inside the mouth of the discharge canal. On several dives, we observed both bass and bluefish moving in the discharge area at the same time. With very little intermingling, the bass were layered at or near the bottom while the bluefish were arrayed above them from mid-water to just below the surface.

Tautog

Ranked fourth in fish sighted (Table 6), tautog were recorded in much lower numbers than in 1990. A substantial decrease in catch per unit effort for this species in 1991 was also noted in project gill-net catches. A comparison of data on fish per dive for this species (Figure 21) indicates that local abundance is still far higher than in 1987 and 1988, but no where near as high as in 1990. It should be noted, however, that the number of tautog observed by divers in the discharge area has fluctuated widely since the inception of observational diving. Tautog generally were found to be milling about the mouth of the discharge canal, most commonly on the inside of the southern-most discharge jetty.

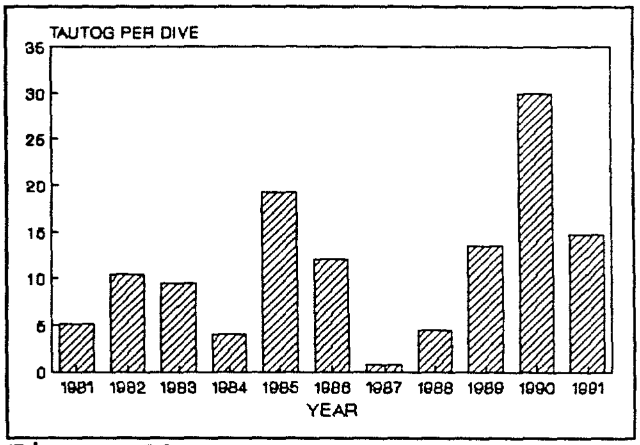

Figure 21. Indices of relative abundance (fish per dive) for tautog observed by divers at Pilgrim Station, 1981-1991.

5. Sportfishing Survey

The Shorefront recreational area at Pilgrim Station was opened to the public in 1991 on the first of April and was closed at the end of October following a severe/five-day northeast storm that caused extensive damage along the western shore of Cape Cod Bay.

Salt water sportfishing is allowed at the Shorefront during daylight hours, and an informal survey of this shore-based fishery was conducted by seasonal public relations personnel from Boston Edison Company. Creel data were obtained during the period of 18 May through 31 August, which included 80 sampling days. Before and after the survey, DMF biologists made spot checks at the Shorefront to monitor sportfishing activity.

A reported 1,492 angler-trips were made to the Shorefront in 1991 during the actual survey and 903 finfish caught, comprising 6 species. The daily average number of shore fishermen at the plant site was 19, which is not much different from last year's mean of 18 anglers per day. Species recorded in the sportfishery in 1991 included two pelagic fish - bluefish and striped bass - and four groundfish - cunner, tautog, pollock, and skate spp. The pooled monthly catch rate peaked in August, averaging 1.0 fish per angler-trip, while the overall seasonal mean was 0.6. In 1990, the overall average catch was 0.4 fish per angler-trip.

No creel data were collected from April through mid-May. From our observations, however, fishing pressure was fairly light in April and early May. Fishing effort (angler-trips) increased throughout the summer, peaking in August. A core group of anglers sought bluefish and striped bass in September and October. However, the number of bottom fisherman and overall effort declined in the fall.

Bluefish (71%) and cunner (27%) comprised 98% of the surveyed sportfish catch. As for monthly catch totals, bluefish and cunner predominated in June at 58% and 35% of the catch, respectively; cunner(66%) and bluefish (30%) in July; and bluefish (90%) alone in

August. The highest monthly catch occurred in August, when 63% of the pooled seasonal total was obtained. Catches by species peaked as follows: bluefish in August, cunner and tautog in July, and striped bass in June. Cunner, tautog, pollock, and skate spp. were taken off the outer breakwater, while bass and many of the bluefish were caught in the discharge outfall area. Some bluefish were also landed in the Intake embayment, where a school of juvenile Atlantic herring abounded this summer.

We made the following observations in the fall. On several occasions in September and October, we witnessed numbers of bluefish swirling and "breaking" in and on the periphery of the thermal plume of Pilgrim Station. Anglers fishing from off the two discharge jetties and from anchored boats hooked numbers of bluefish on surface lures (mainly poppers). These fish caught in the fall were not included in the sportfishing survey records, but undoubtedly would have increased substantially the anglers' success statistics.

6. Cunner Tagging and Aging

We have tagged cunner to aid our investigation of their movement patterns and spatial distribution in relation to the rock structure (with emphasis on the outer intake breakwater) in the Pilgrim area and to the thermal discharge from the Power Station. Our intent is to increase information on the behavior and dispersion of local cunner, stressing their susceptibility to impact of the effluent current. Our collaborative aging work is ongoing to characterize the age-structure of the local cunner population as we tag and release fish off the plant.

This species forms discrete, local populations that inhabit temperate marine rocky reefs - including ledges, outcrops, and man-made rock structures, e.g., jetties and breakwaters - that serve as refuge areas. They are bottom fish that occupy small home ranges, exhibiting only seasonal inshore/offshore movements that are temperature regulated.

Cunner were frequently sighted by us, while we were diving in the Pilgrim area. They often reside under rock outcrops and within the interstices of the outer intake breakwater at Pilgrim Station during the warmer months. The large boulders comprising the breakwater provide substrate for attachment of macroalgae and sessile fauna that serve as cover and a food source, respectively. The rocks and associated crevices provide shelter (home sites) for this structure-oriented fish which requires a safe haven during its nocturnal sleep phase. Cunner are active during the daytime and often aggregate in loose foraging groups to feed on planktonic organisms in the water column and on epibenthic and infaunal species on current-exposed surfaces of hard substrates.

During August and September of 1990, we captured and tagged 84 cunner just seaward of the outer intake breakwater at a reference location. In late May 1991, we resumed trapping cunner. Numbers of cunner were obtained off the outer breakwater at this time; some were ripening. From these captured fish, we retained a sub-sample for aging, releasing the others. Between June 20 and October 10, 1991, we made 18 outings to tag cunner off Pilgrim Station. We captured 1,515 cunner in 1991, tagging 654 ($\geq$ 11 cm total length). All tagged fish were released in the area of capture, while most of the untagged fish likewise were released. This allowed for the possibility of recaptures.

Of the fish captured (1,515) in 1991, 77% were taken in the reference area and 23% in the surveillance area. Of the fish tagged (654) in 1991, 76% were captured, tagged, and released in the reference area, while 24% were tagged in the surveillance (discharge) area. Over the last two years, a total of 738 cunner has been tagged off Pilgrim Station. In 1991, 53 cunner were recaptured, representing 7.2% of the total tagged to date. Of the recaptures, 40 were resightings by biologist-divers on SCUBA surveys, 11 were recaptured in baited eel pots, one was taken in an experimental gill net, and one was caught by an angler at the Shorefront.

As to tagging location for the recaptures, all but one were tagged in the reference area; the one exception was tagged in the surveillance area. All returns came from the reference area except for one, which came from the gill-net station location. The time-at-large included a few fish that were recaptured the same day they were tagged to cunner at large for almost a year. Most of the recaptures were taken within a month of their tagging.

From the collaborative aging work done on cunner (n= 56) off the Power Plant this summer, eight age-groups were present in the sampling: ages 2-8, and 10 (Table 7). Young-of-the year and yearlings were observed in the study area but were not captured in the aging sample. The fish that were aged ranged in size from 8-30 cm total length (T.L.). All 8-10 cm TL cunner were two year-olds. Forty-three percent of the fish aged were two and three year olds.

The majority of fish tagged were presumably two and three years old (61%), ranging in size from 12-14 cm T.L.

Table 7. Age composition in number of fish and (percent of total) with total length measurements (cm) of cunner captured off Pilgrim Station in 1991.

Age Group	Number of Fish	Mean Length	Standard Deviation	Range of Lengths
II	14 (25)	10	1.5	8-13
III	10 (18)	13	1.1	11-14
IV	9 (16)	16	1.1	15-18
V	9 (16)	17	1.1	15-19
VI	5 (9)	20	0.7	19-21
VII	5 (9)	21	2.4	18-24
VIII	3 (5)	24	0.0	24
X	1 (2)	30	0.0	30

V. HIGHLIGHTS

Lobster - Commercial Fishery

1. Catch statistics and biological data for the commercial lobster fishery in the Pilgrim area were collected from 5,562 lobster sampled from May through October, 1991.
2. Catch per unit effort of total lobster (2.3 CTH) decreased 8% from 1990 (2.5 CTH)
3. Legal catch rate decreased 16% from last year, declining from 0.44 to 0.37 legals per trap-haul.

Lobster - Research Study

1. Fifty-three sampling days of research pot fishing (June to September, 1991) yielded 9,682 lobster (57% male; 43% female) captured from 2,650 trap-hauls, with legals comprising 10% of the catch.
2. Study area catch rate of legals ($\geq$ 82.6 mm carapace length-CL) declined 12% from 1990, the second consecutive annual decline in the six-year time series. Study area sublegal (< 82.6 mm CL) catch rate remained unchanged from 1990, after having risen annually since 1986.
3. Only 1.5% of the research catch of female lobster were ovigerous (carrying eggs).
4. Carapace lengths of lobster in research catches ranged from 33-114 mm, and averaged 75.3 mm, which is slightly smaller than the mean size from last year.
5. The cull rate remained at 29%, identical to last year's value.

Nearshore Groundfish

1. Twenty-one fish species were collected by bottom trawling in the nearshore area of Pilgrim Station.
2. The average catch per standard tow for all species and stations combined declined to 3.9 fish/tow.
3. Atlantic herring ranked first in total catch, however, this was due primarily to the capture of 300 juveniles during one tow off Priscilla Beach. This species is rarely caught by our trawl.
4. Winter flounder ranked second in total catch at 14.5%. Catch-per-unit-effort declined for the fifth year to 0.6 fish per tow.
5. Little skate ranked third in total catch (9%); overall abundance dropped by 50% to 0.4 fish/tow.

Pelagic and Benthi-pelagic Fishes

1. Comprising 20 species, 1,012 finfish were gill netted during 11 overnight sets.
2. Annual mean CPUE of pooled species (82.3) increased 20% from 1990.
3. Pollock ranked first, comprising 41% of the catch. Atlantic herring was second (23%), and cunner was third (6%).

Shore-zone Fish

1. Twenty-seven finfish species were haul seined from June through October, 1991 in the Pilgrim area; three of these species - Atlantic silverside , Atlantic herring, and sand lance - comprised 99% of the catch.

2. Increases from 1990 in the catches of Atlantic silverside, Atlantic herring, and sand lance contributed to the increase in the overall 1991 seine catch rate in the Pilgrim area.
3. Seine catch rates (pooled species) increased from last year at three of the four sampling sites.
4. Atlantic silverside continued to dominate seine catches, comprising 46% of the total. They ranked first in overall catch per unit effort and in percent frequency of occurrence in the catches. Their relative abundance almost doubled from last year.
5. Atlantic herring (all juveniles) ranked second in seine catch abundance, with most taken in the Intake embayment at Pilgrim Station.
6. The total number of fish seined was greatest in the Intake, but species diversity was highest in the catches at Long Point.

<u>Underwater Finfish Observations</u>

1. A total of 1,915 fish, comprising 8 species were observed during 13 dives in 1991.
2. Total number of fish observed was 25% lower than in 1990, due primarily to decreased sightings of tautog, striped bass, and bluefish. Observed fish were distributed as follows: 61 % in the denuded zone, 28% in the control zone, and 10% in the stunted zone.
3. Cunner was the most common species seen (64% of the total) and was found at all stations. Fewer small cunner were sighted than in 1990.

4. Fish per dive indices for striped bass, and bluefish were the second highest recorded for the dive study.
5. Far fewer tautog were sighted than in 1990 and were found primarily in the discharge area.

Sportfishing Survey

1. Sportfishing was surveyed at the Pilgrim Shorefront from mid-May through August 1991.
2. A reported 1,492 angler-trips were made by shore-based fishermen to the Shorefront and about 900 fish, representing 6 species, were caught during the survey.
3. Bluefish (71%) and cunner (27%) comprised 98% of the surveyed recreational catch.
4. Overall effort and catch were up from last year. The catch of bluefish was up, but striped bass catches were down.

Cunner Tagging and Aging

1. Collaborative aging work is ongoing to characterize the age-structure of the local cunner population off Pilgrim Station.
2. The fish aged this summer measured 8-30 cm in total length (TL) and were from 8 age groups - 2-8 and 10 year-olds.
3. We tagged 84 cunner in 1990 and 654 cunner ($\geq$ 11 cm TL) in 1991 off Pilgrim Station using Floy T-bar anchor tags.
4. In 1991, 53 tagged cunner were recaptured, representing 7.2% of the total tagged to date.
5. The time-at-large ranged from recaptures the same day of tagging to fish at large for almost one year.

6. From recaptures, movement of cunner off Pilgrim Station appears to be limited at least during the warmer months of the year.

VI. ACKNOWLEDGEMENTS

The authors thank staff members, John Chisholm and John Costa, for collecting and processing field data and acknowledge Neil Churchill, Paul Caruso and H. Arnold Carr who assisted in diving operations. We thank Chris Kyranos for his valuable assistance in lobster sampling, and Raymond Dand and Robert Ellenberger for collecting sportfish data at the Pilgrim Shorefront. Jay Burnett of the National Marine Fisheries Service at Woods Hole aged cunner collected from the Pilgrim area using otoliths and scales. Much thanks to Kim Trotto of the Division for word-processing various sections of this report. Finally, we appreciate the continued guidance of Robert D. Anderson of Boston Edison Company, W. Leigh Bridges of the Division, and members of the Pilgrim Administrative-Technical Committee. Their input on study programs and editorial comments on project reports and papers have been most helpful.

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ANNUAL REPORT
ON
ENVIRONMENTAL IMPACT MONITORING
OF
PILGRIM NUCLEAR POWER STATION

(IMPACT ON MARINE INDICATOR SPECIES)

Project Report No. 52 (January-December, 1991)
(Volume 2 of 2)

By

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Plate 10. A winter flounder on the bottom near diving station D_1 (approximately 50 m seaward of the discharge canal) in the "denuded" zone off Pilgrim Station. An important commercial and recreational fish, flounder inhabit the Pilgrim area throughout the year and have been used as an "indicator" species to assess stress imposed by the release of the heated effluent.

Plate 11. Pictured is the thermal effluent discharging into Cape Cod Bay and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background by the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

Plate 12. Striped bass aggregate in the thermal discharge current at Pilgrim Station, often swimming just off the bottom into and out of the discharge canal. Bass are attracted to moving water as a feeding ground.

I. EXECUTIVE SUMMARY

In accordance with the Pilgrim Nuclear Power Station NPDES Permit requirements of the Massachusetts Division of Water Pollution Control and the U.S. Environmental Protection Agency, marine fisheries monitoring and reporting were completed for 1991. Fisheries data were collected to assess impact of Pilgrim Station. We emphasized data comparisons of high operational years with years of low or no output.

During the past year, operational status at Pilgrim Station was 58.4% of capacity. The following is a summary of findings.

- Sportfish and gill-net catches and diver observations of bluefish and striped bass indicate that the heat and current of the thermal discharge effect a shift in the spatial distributions of both species in the Pilgrim area.
- The cumulative effects of entrainment, impingement, and sportfishing have contributed to a reduction in the local cunner population.
- Our research lobster program indicates a negative correlation between sublegal lobster catch rate at sampling stations in the discharge area and the release of the cooling water discharge.
- While diving, we have observed few lobster residing in the immediate outfall area when the plant is operating most likely because of the discharge current which would limit their mobility.
- Losses of Atlantic silverside, Atlantic menhaden, winter flounder, and tautog via entrainment, impingement, sportfishing, and gas bubble disease do not appear to be significant.

Plate 1. Biologist collecting length-frequency data from the catch of a commercial lobsterman in the proximity of Pilgrim Station. Lobsters constitute the area's most valuable fishery resource.

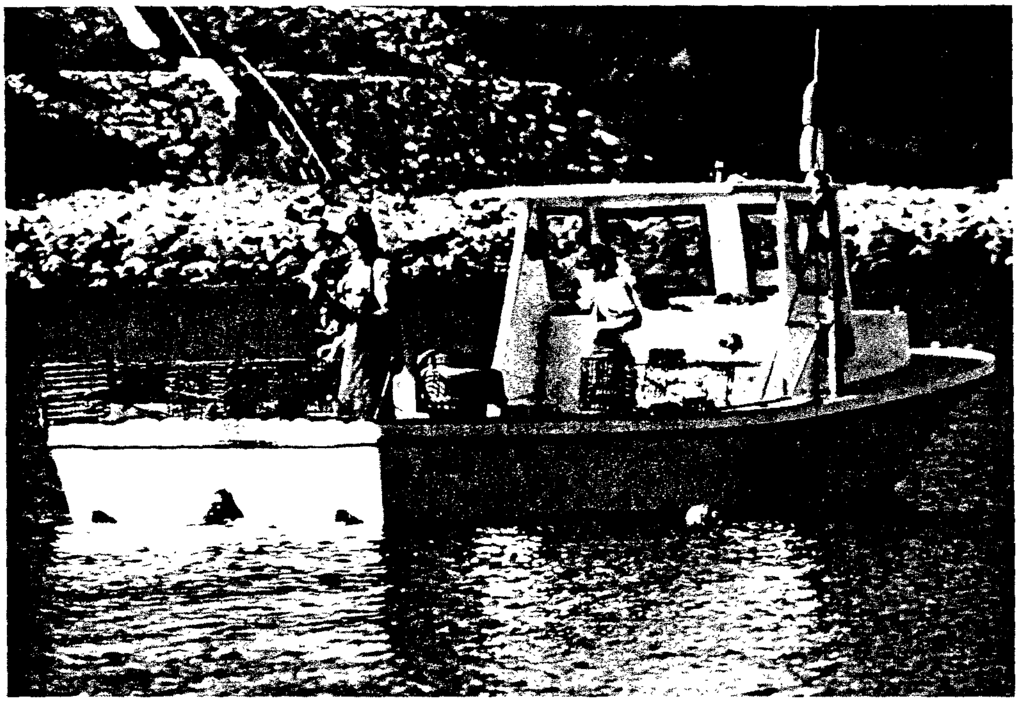


Plate 2. Operations aboard a fishing vessel used during the experimental lobster study. This investigation is designed to better assess the impact on lobsters of the thermal effluent at Pilgrim Station.

Plate 3. Retrieval of the experimental gill net after a standardized overnight set in the thermal plume area. Caught in the net is a smooth dogfish, a common summer migrant in the Pilgrim area.

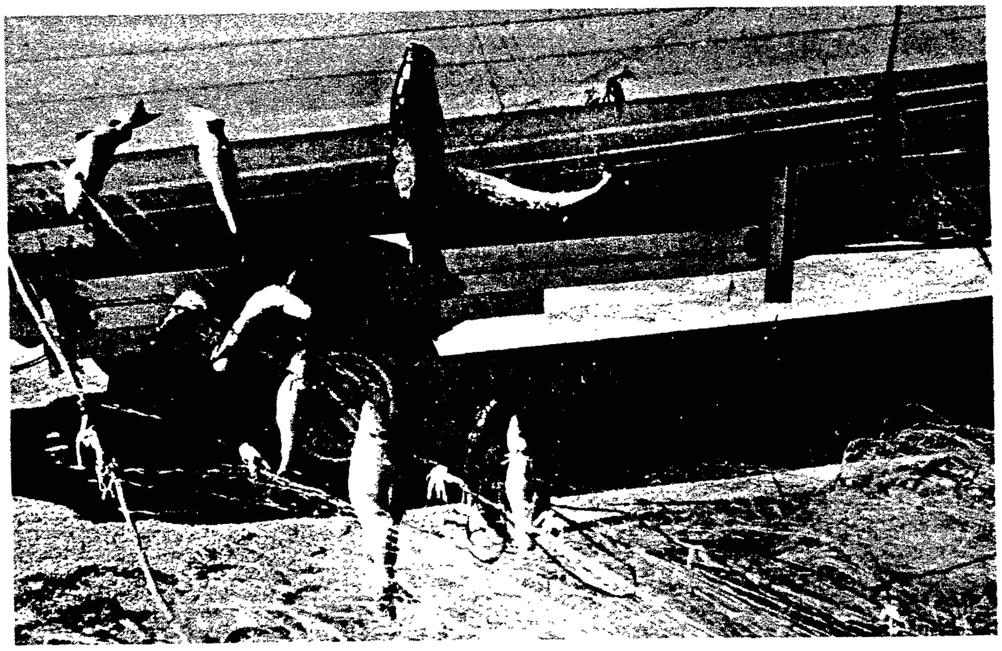


Plate 4. Fishes caught by gill net in the area of the thermal plume at Pilgrim Station. Gill-net catches include commercially important species, e.g., Atlantic cod, pollock, Atlantic mackerel, striped bass, and winter flounder.

Table 1. Indicator species selected to assess impact of Pilgrim Nuclear Power Station.

Species	Background History	Basis for Selection as an Indicator Species	Possible Sources of Impact	Sampling Method
American lobster	RIS	d,r,c,s	I,E,T/C	intake screens/trap/trawl/diving/gillnet
Atlantic silverside	RIS	d,r	I,E,T/C,G	intake screens/haul seine/trawl
Atlantic menhaden	RIS	d,c	I,E,T,G	intake screens/seine/gill net
Cunner	RIS	d,r,s	I,E,T/C	intake screens/diving/seine/ gill net/sportfish catch
Winter flounder	RIS	d,r,c,s	I,E,T/C	intake screens/trawl/diving/seine/sportfish catch/gillnet
Tautog	IS	d,c,s,r (seasonally)	I,E,T/C	intake screens/diving/gill net/sportfish catch
Bluefish	IS	c,s,d (seasonally)	T/C,I	diving/gill net/sportfish catch/seine/intake screens
Striped bass	IS	c,s,d (seasonally)	T/C	diving/gill net/sportfish catch

RIS - representative species selected in the original 316 (a and b) Demonstration Document to assess Pilgrim Station impact (Stone and Webster 1975).

IS - indicator species; was not an original RIS but after 2 decades of data collection, we added it to the list.

d - a dominant species in the Pilgrim area.

r - a local resident

c - commercial importance

s - recreational importance

I - impingement

E - entrainment

T/C - discharge current effects: thermal/current

G - gas bubble disease

III. RESULTS AND DISCUSSION

A. PHYSICAL (ABIOTIC FACTORS)

1. Power Output and Thermal Capacity

When assessing impact of the thermal discharge from Pilgrim Station on marine populations in the offsite waters of western Cape Cod Bay, we must consider the station's capacity factor (MDC net percent). This index of operational status approximates thermal loading in the outfall. At 100% MDC, there is a permitted, allowable maximum temperature rise (ΔT) in the effluent of 18° C (32° F) above ambient. Since power production began in November 1972, the annual MDC at the station has ranged from 0.0% for outage years (i.e., 1987, 1988) to the high of 84.4% in 1985 (Figure 1). The power level was 0.1% in 1984, which was essentially an outage year. In addition to 1985, other high output years that exceeded 80% were 1979 and 1983. The output in 1991 averaged 58.4% of capacity. The overall 19-year mean is 47.4%, with 10 of the years exceeding this average (Figure 1).

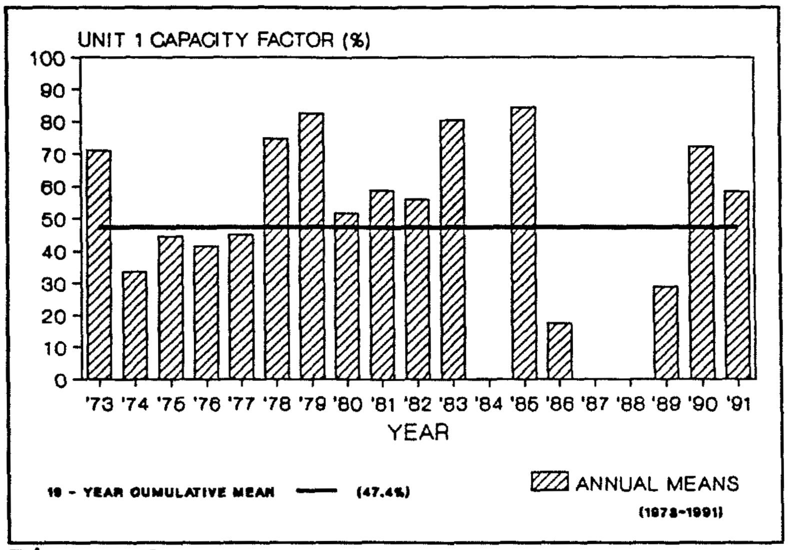


Figure 1. Annual means and 19-year cumulative mean Pilgrim Station Unit 1 Capacity Factor (MDC Net %) for 1973-1991.

In Volume II, data for selected species are analyzed and comparisons stressed between the years of 1983, 1985, and 1990 (high operational output) and years of low or no output: 1984, 1986-1989. In 1991, the thermal capacity was 0.0% for May-July, 28.5% in August, and 23.7% in November because of outages.

2. Discharge Current

The circulating seawater pumps at Pilgrim Station induce a localized current. The once-through cooling-water system draws water from the intake channel to remove waste heat, primarily from the plant's condenser tubes. The waste water is discharged in a current of water back to Cape Cod Bay. The moving water, which can reach velocities approaching 2.1 m/sec (7 ft/sec) at low tide, has a scouring effect on the Bay bottom. The two circulating seawater pumps draw in 1.17 x 10^6 liters/minute (310,000 gal/minute) of water from the intake embayment. In late November 1991, we took measurements of the discharge current velocity on an ebbing tide with both circulating pumps operating. At 100 m from the discharge canal we obtained velocity measurements of 84 cm/sec (2.8 ft/sec) at the surface and bottom. Auster (1987) reported that a tidal current velocity approaching 50 cm/sec (1 kt) is current-limiting to many reef fish species.

Both circulating water pumps were run simultaneously for most of 1983 and 1985 and all but the months of March and April in 1990. During the outage in 1984, both pumps were off from late March to mid-August, thus markedly reducing discharge flow (Figure 2). In 1986, both pumps were operated from January to early March; but thereafter, during the prolonged outage, only one pump was operated at a time. As the outage continued into 1987, both circulating

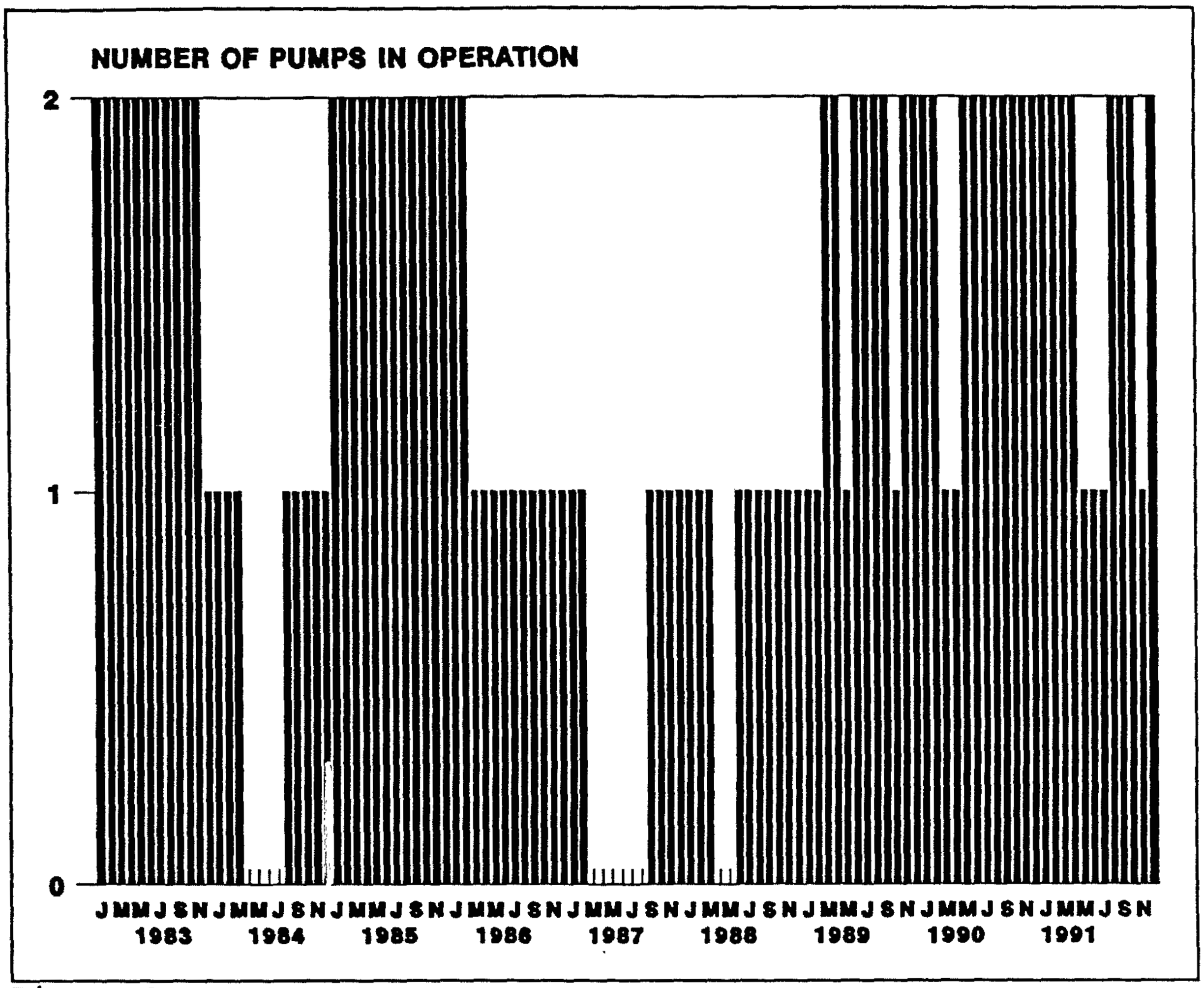


Figure 2. Circulating seawater pumps operating by month at Pilgrim Station, 1983-1991.

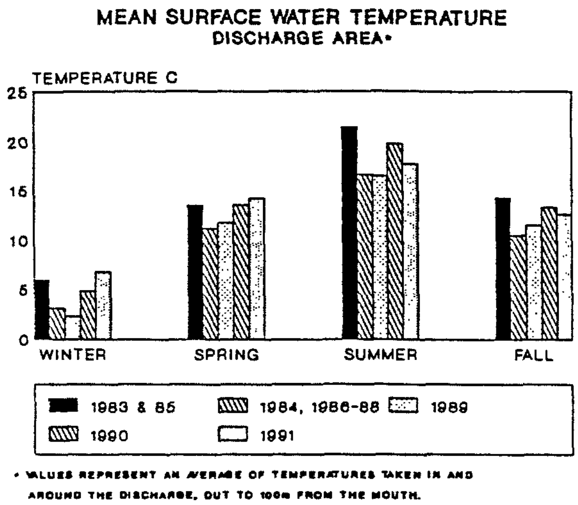
pumps were turned off from late February through early September, while one pump generally ran for the rest of the time. In 1988, with the outage still ongoing, one pump was on for most of January-March and June-December, but from mid-April to early June, both pumps were again off. In 1989, the plant gradually increased power production as it returned to full operational status. One pump was operated in January, February, May and October; otherwise, both were run. In 1991, only one pump was run from May-July and in much of November during outage periods.

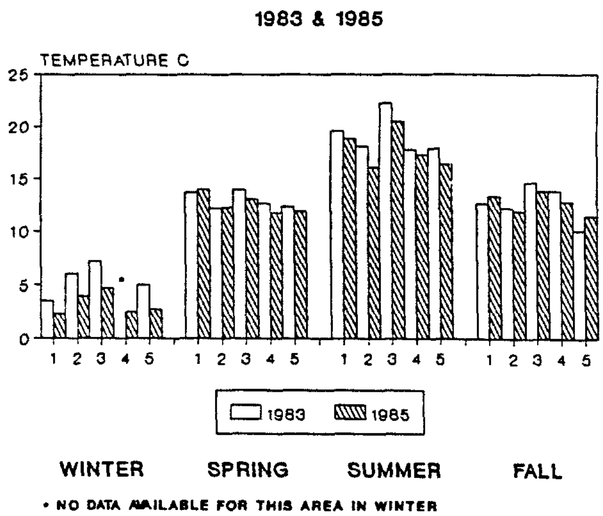
3. Water Temperature

Water temperatures in the Pilgrim area over the last nine years (1983-1991) were highest in the discharge outfall (Area 3) in 1983 and 1985 (>80% power plant capacity) and in 1990 (> 70% output), as a result of the waste heat (Figure 3). Conversely, surface temperatures in the discharge area were markedly lower for the outage years: 1984, and 1986-88, when waste heat and current were minimal. In 1989, with Pilgrim's thermal capacity averaging 28.9%, there was some thermal elevation at the surface in the immediate receiving waters. The years, 1983 and 1985, show the maximum temperature difference that occurs between the discharge area and other sites during the seasons and, therefore, the impact potential of waste heat on the environment (Figure 3).

With Pilgrim Station fully operational, the near-field area impacted by the thermal discharge has contained a 1,100-1,400 m^2 'denuded' zone, believed to be primarily a result of scouring. A peripheral zone of 'stunted' algal growth occurs of about 1,900 - 2,900 m^2 in area, most likely resulting from the thermal component of the discharge. In late November 1991 on an ebbing tide, we ran a transect perpendicular to shore, out from the discharge structure, and measured surface and bottom water temperatures. We found a temperature rise at 100 m on the surface and bottom.

When Pilgrim Station has operated at full capacity, an allowable temperature rise of 18° C can occur in late summer in the effluent water. The highest temperature recorded in the thermal plume has been 32° C, recorded both on the surface and bottom. In





AREA KEY:

1. GRAY'S BEACH & LONG POINT
2. WARREN COVE & ROCKY POINT
3. DISCHARGE AREA
4. INTAKE
5. WHITE HORSE & MANOMET POINT

Figure 3. Surface water temperatures in the Pilgrim area averaged by season for the years, 1983-1991.

1984 (outage year), 1986 (outage April-December), and 1987-88 (outage years), water temperatures in the outfall area mirrored ambient.

B. IMPACT OF PILGRIM STATION ON INDICATOR SPECIES

1. Cunner

Background

The cunner is an abundant groundfish resident in the inshore waters off Pilgrim Station. Being shelter dependent, they reside in rocky areas that abound off the Plymouth shoreline, including the man-made breakwaters and jetties at the power station. Cunner occur in discrete populations and are more likely to be measurably affected by point-source pollution than a species which exists as essentially one interbreeding population throughout an extensive geographical range, e.g., Atlantic menhaden. A good indicator organism to assess plant impact, cunner have small home ranges and, as such, may be exposed to increased sportfishing mortality and potential effects of inshore pollutants. Cunner are especially vulnerable after dark, since low responsiveness to stimuli, characteristic of the sleep state of labrid fish, reduces their ability to avoid environmental stresses that might occur at night.

From recaptured fish in our cunner tagging study off Pilgrim Station, we have evidence of their site tenacity. All but one of the returns came from the area of tagging, indicating the fish were relatively sedentary at least during the warmer months.

Gill-net, diving, and creel sampling data document that the cunner is a dominant fish off Pilgrim Station. The power plant's intake breakwaters and discharge canal jetties provide added structure to the naturally occurring glacial till for a temperate-water reef community, of which the cunner is a member. The large boulders provide shelter imperative to this species sleep phase and cover to escape current velocities that impair the fish's maneuverability.

Normally distributed at depths of 3 m to 10 m, some populations do occur in deeper water (Grosslein 1969). Year-round residents throughout much of their range (Green and Farwell 1971; Olla et al. 1975), cunner will move seasonally to deeper water to escape cold temperatures. In the Gulf of Maine (Bigelow and Schroeder 1953) and off Newfoundland (Green and Farwell 1971), cunner activity was found to decrease at water temperature below 8° C. Olla et al. (1975) found that in the fall at temperatures of 5-6° C, cunner become inactive and then torpid, remaining so until the water warms above 6° C in the spring.

Life Stages Impacted and Sampling Protocol

Potentially, cunner may be impacted by Pilgrim Station via mechanical and waste heat/current effects. Cunner appear to spawn near the power plant. We captured ripe cunner seaward of the outer intake breakwater in May 1991. Because the eggs and resultant larvae are pelagic, they are subject to entrainment in the plant's circulating seawater system.

Routine entrainment sampling at Pilgrim Station provides quantitative data on the early life stages of cunner drawn into the plant's condenser tubes. Juveniles and adults (aged to 10 years off Pilgrim Station) occur off the plant, including in the intake embayment, and are subject to impingement on the travelling-water screens. Impingement data routinely collected at the plant and haul seine sampling in the intake provide information on plant-induced mortality, seasonal occurrence, and general abundance of cunner. The discharge current laden with waste heat and periodically with chlorine can influence all life stages of cunner in the receiving waters. Gill-net, observational dive, and sportfish creel sampling together with tagging provide data on cunner in the discharge area and its environs. Cunner are expected to be most affected by station operation during summer and fall when they are active and most abundant off Pilgrim Station.

Impingement and Entrainment Effects

Impingement

Adult and juvenile cunner have been entrapped on the intake screens at Pilgrim Station. This species has been among the dominates impinged from 1976-1980 (Lawton and Anderson et al. 1984) and from 1981-1991. In 1991, cunner were first impinged in January and last in October, leading the impingement collection in May. Over the years, more cunner have been impinged from June through September.

Impingement can be relatively high as it was in 1980, when about 1,700 cunner were impinged at Pilgrim Station. There is some survivorship of impinged cunner at the power plant, e.g., 24% in 1989. Nevertheless, an impingement of this magnitude could impact the local population in a given year when combined with sportfishing mortality and a depressed stock size. The present population appears to have declined in abundance.

Entrainment

Numbers of cunner eggs and larvae are entrained at Pilgrim Station every year. The labrid and Labridae - *Limanda (Pleuronectes)* groups dominate collections of fish eggs at the station during the history of plant operation, comprising >90% of the eggs entrained. Johansen (1925) reported cunner spawn from May to August in New England and Canadian waters. Williams (1967) reported spawning temperatures of 10°- 26° C.

In 1991, cunner eggs were entrained at Pilgrim Station from May-September but were most abundant in June samples. An especially high density of cunner eggs was entrained at the station in June 1989 which might have explain the unusually large number of 5 cm cunner observed by us while diving just outside the discharge canal in 1990. Over the years of plant operation, cunner eggs have been entrained as early as March or April when ambient water temperature has been as low as 2.6° C (Scherer 1984). Scherer (1984) hypothesized that mature cunner may ripen and spawn earlier in the area warmed by the thermal discharge.

In 1991, cunner larvae were entrained at Pilgrim Station beginning in late May. Highest densities were obtained in June, while the last larvae were sampled in September. Unusually high densities of cunner larvae were entrained in June of 1989 and in July and August of 1990. No such densities were obtained in 1991.

Marine Research, Inc. (1991) concluded that large quantities of spawn (fish eggs and larvae) can be entrained at Pilgrim Station during a year and are assumed to be lost from the respective populations. A high percentage of these are cunner.

Discharge and Sportfishing - Related Effects on the Population

<u>Population size</u>

In 1991, cunner ranked in its traditional third position in the hierarchy of gill-net catch composition off Pilgrim Station. The local population appeared to be fairly stable from 1971 to 1976 (Figure 4); over these years, the mean catch rate was 22 cunner per standard gill-net set. From 1977 to 1983, the yearly catch rates generally doubled ($\overline{X}$ = 41 fish per set). This suggests there was a marked change in distribution or abundance of the local population. The catch rate had been declining gradually from 1981 to 1984, but then dropped sharply in 1985, remaining at a low level thereafter. Over the last seven years, the gill-net catch rate of cunner has declined by 70% from the previous eight years, averaging only about 12 fish per set. The local stock evidently has declined, with the 1990 and 1991 catch rates of recruitable cunner being the lowest on record (Figure 4).

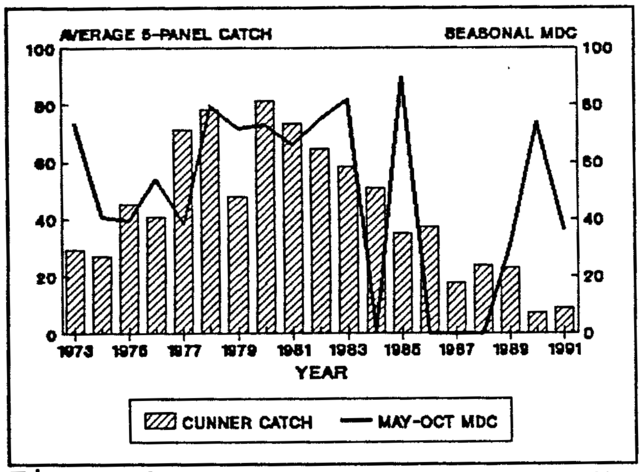


Figure 4. Average seasonal standard 5-panel gill-net catch for cunner and respective seasonal MDC Net % at Pilgrim Station, 1973-1991.

<u>Discharge:thermal/current</u>

Temperature tolerance data on cunner (Kinne 1969;Briggs 1973) suggest that the waste-heat effluent from Pilgrim Station should not cause overt mortality of this species outside the discharge canal. However, during the late summer and early fall when ambient water temperatures peak in Cape Cod Bay (Lawton et al. 1983), if the power plant is fully operational there likely is created an exclusion area to cunner within and just outside the confines of the discharge canal. Observations during our research dives in the discharge area (limited to flood tide) in August and September 1991 revealed there were substantially fewer cunner at the mouth of the discharge than out at 60 m in the path of the thermal plume. We measured bottom temperatures in excess of 30° C in September at the discharge canal mouth. These temperatures are stressful to cunner and would be avoided if possible. Kinne (1969) reported the upper thermal tolerance for adult cunner to be 29° - 30° C at an acclimation temperature of 18° - 22° C.

During spring, temperatures in the thermal plume outside the effluent canal at Pilgrim Station are ideal for the hatching of cunner eggs. According to Williams (1967) cunner hatching occurs in less than 48 hours at 21.1° - 22.2° C. The preferred temperature range of adult cunner is 13° - 26° C (Stone and Webster 1975). In autumn, ideal conditions for cunner growth should exist immediately outside Pilgrim's discharge channel.

We graphed plant output, i.e., thermal capacity, for the spring and summer seasons, when cunner are most active inshore, versus the gill-net catch rates for cunner over the years (Figure 4). When catch rates for the period prior to the crash in cunner stock abundance were statistically compared to seasonal power plant

MDC for operational years, we found a significant positive correlation ($P \leq 0.05$) and a highly significant F ratio ($P < 0.01$) using regression analysis. Thirty-nine percent of the variability in gill-net catch rate could be explained by variation in plant load.

Eleven years of observations made during the course of 146 SCUBA dives off Pilgrim Station revealed that cunner has been the finfish species of greatest abundance in the vicinity of the outfall. For example, in 1990 and 1991, 53% and 64%, respectively, of the fish documented by project divers were cunner.

Diving observations and gill-net data suggest that cunner of about 5 cm and larger are attracted to Pilgrim's discharge flow at high tide. Woolner and Lyman (1984) reported that bottom-feeding fish, for the most part, are more active when the tide is moving as opposed to slack. During plant operational periods, and at high tide, we have observed greater numbers of the larger size class individuals in the faster current region of the 'denuded zone' than in either of the peripheral 'stunted' or 'control' zones. Even without a great amount of waste heat released at the station, the generation of a water current produced by at least one of the two circulating seawater pumps at Pilgrim Station is of sufficient velocity to shift the small-scale spatial distribution of cunner by size class. However, during times when little or no discharge current was released from the power station, more cunner were found in the 'control' area.

Cunner are attracted to moving water to feed, as they will forage on surfaces exposed to current for epifaunal and infaunal prey and in the water column for planktonic organisms. Olla et al. (1975) observed that when cunner are feeding in the water column with a current present, they will face into the moving water while visually searching for food to be carried by them in a scan-and-pick feeding mode.

It is known that small cunner, e.g., 2-3 cm fish (young-of-the-year), do not move far from their home shelter. Furthermore, the speed of the effluent current at Pilgrim Station, which can reach 2.1 m/sec (7ft/sec) at low tide, is too strong for these small fish to spend any amount of time in the discharge when the plant is operating. When small cunner abound in the Pilgrim area and if the plant is operational, these individuals most often will reside in the 'control' area. Auster (1987) found at different sites throughout New England that larger cunner foraged further from reef substrate and on current exposed surfaces for longer time periods. As current velocity decreased, he found smaller size classes of cunner moved up into the water column out of the reef infrastructure and onto current-exposed surfaces to feed. As the speed of the current increased the process was reversed.

Sportfishing Effects

Over the years that the Pilgrim Station Shorefront has been open to the public, cunner often has led the shore-based sportfish catch. Cunner are caught readily by anglers bottom fishing off the outer intake breakwater at the station. They ranked second in the sportfish catch at the Shorefront in 1991. In mid-July, an angler caught one of our tagged cunner on the seaward side of the outer breakwater.

Cunner have small home ranges which they occupy for an extended time period. This exposes them to the potential of increased sportfishing mortality. Most cunner caught at Pilgrim Shorefront have been allowed to die, and fishing mortality on the local population can be high. In 1983 and 1985, for example, about 2,600 and 3,500 cunner, respectively, were landed by anglers at the Shorefront. Interestingly enough, the gill-net catch rate of cunner for 1985 dropped precipitously off Pilgrim Station. To address fishing mortality, we are encouraging fishermen, via posters placed at the shorefront, to release their catch alive if the cunner are not kept for consumption. Presently, there is no market for the sale of cunner.

2. <u>Lobster</u>

Background

The American lobster inhabits rock-strewn ledge and sand bottoms of Cape Cod Bay and is the object of intensive commercial and recreational fisheries in the Pilgrim area. It takes approximately seven to eight years for lobster to molt to legal size in Cape Cod Bay. Fertilized lobster eggs, typically extruded in late summer, are carried through the winter by females and hatch from late spring until summer. The young lobster enter a three week planktonic stage before taking to the bottom. Entrainment at Pilgrim Station of lobster larvae would be expected during late spring and summer.

Juvenile and adult lobster move somewhat offshore to deeper water to overwinter. In April as water temperatures warm, lobster move inshore and remain until the late-fall offshore migration. It is during their inshore stay that lobster may be either impinged at the plant intake or affected by the waste heat and discharge current at Pilgrim Station.

Life Stages Impacted and Sampling Protocol

Any potential impact of Pilgrim Station on the lobster would most likely occur during the benthic-dwelling juvenile and adult stages. Few lobster larvae have been entrained over the years of operation at Pilgrim Station. Intake impingement sampling has recorded low numbers of juvenile lobster over the years. For example, in 1991, a total of 51 sublegal lobster (mean size 47 mm CL) were collected on Pilgrim's intake screens, which equates to almost 900 sublegal lobster annually impinged at 100% operation of Pilgrim Station.

We typically capture quantities of sublegal lobster from May through July during our trawling survey. However, trawl lobster catches are not used to assess power plant impact, due to sporadicity and unpredictability of lobster occurrence in the net. Gill-net catches of juvenile and adult lobster are low. To ascertain impact of plant operation on the local lobster population, we rely on our trap sampling programs: commercial and research. Discussion of the results of these programs for 1991 follows.

Discharge Related Effects

Commercial Lobster Pot-Catch Fishery

Pooled lobster catch statistics from the surveillance (discharge) quadrants (H-11, H-12, I-11, and I-12) were compared with data from the reference quadrants (E-13, E-14, and F-13) located in Warren Cove (see Figure 2 in Vol. 1) to assess impact of Pilgrim Station on the local lobster population and fishery. Realistically, we can compare surveillance and reference area catch rates from 1984-91 (1985 and 1990 being the only high output on-line years in that period) because the same lobsterman supplied all of the data. Catch data from 1983 are included in our discussion because this also was an on-line year of high operational status.

Males outnumbered females in the commercial catch from the Pilgrim study area in 1991, comprising 55% of the total. This preponderance of males existed at both the surveillance (52%) and reference (61%) areas.

As in the previous five years, the percentage of culls in the surveillance area (20%) in 1991 was lower than in the reference area (25%). A chi-square test (Sokal and Rohlf 1969) showed this difference to be non-significant ($P = 0.06$) for the first time in six years. An increase in the lobster cull rate is promoted by lobster fishing and bottom trawling (Keser et al. 1983; Estrella and McKiernan 1986). Both study locations are subject to intensive commercial lobster fishing. In addition, commercial bottom trawling in Warren Cove is seasonally (November through March) conducted for groundfish; this may account for the higher cull rate there.

The 1991 mean commercial legal lobster catch rate (expressed as catch-per- trap-haul, or CTH) increased 30% and 9% at the reference and surveillance sites, respectively (Figure 5). In the surveillance area, CTH increased only slightly from 0.32 to 0.35 legals per trap-haul, while in the reference area the catch rate rose from 0.27 to 0.35. Annual lobster catch rates in the impact area do not appear measurably different between years of on-line and off-line plant status, in that the CTH ratios of impact versus control sites from the high operational years of 1983 and 1985 are comparable with the ratios from the off-line years of 1984 and 1986, as is that of the on-line year 1990 contrasted with that of the off-line year 1988 (Figure 5). Since 1987, catch rate in the impact area has been equal to or greater than that of the control area. There is no apparent relationship in the annual catch ratios between these study sites to the annual operational status of the Pilgrim Power Plant.

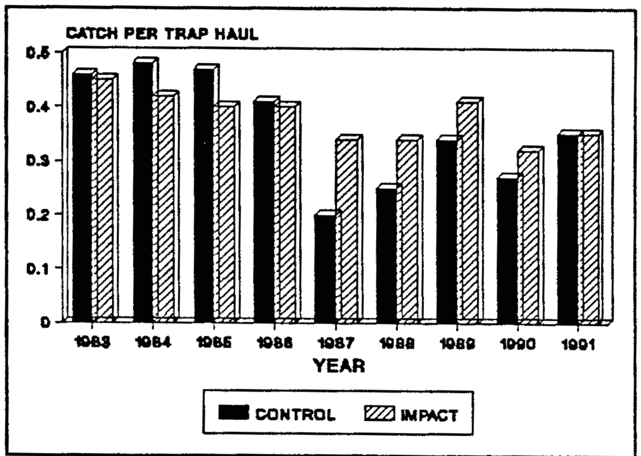


Figure 5. Annual legal lobster catch per trap-haul in control and impact areas near Pilgrim Station, 1983-1991.

A brief discussion of the annual commercial lobster catch rates (Figure 6) and landings for western Cape Cod Bay and for Massachusetts' coastal waters in general provides a basis with which to compare annual Pilgrim Station impact and surveillance area lobster catch rates. A cooler ambient temperature regime in 1984 (Estrella 1985) apparently depressed or at least delayed the early season lobster molt, which, in turn, would have affected subsequent recruitment to legal size and would also have lowered lobster activity (Campbell 1983; Estrella 1985). This is reflected in the mean commercial catch rate of 0.48 legals per trap-haul in western Cape Cod Bay in 1984 (Lawton et al. 1985), which represented a reduction of 30% from the 1983 value (0.68) (Figure 6). According to Estrella (1985) and Estrella and McKiernan (1986), the coast-wide commercial catch rate (catch per trap haul) of marketable lobster in 1984 was lower than in 1983 and 1985 by 19% and 20%, respectively.

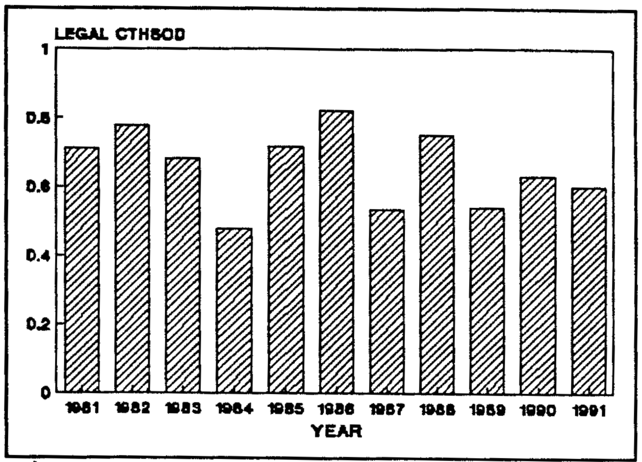


Figure 6. Commercial legal lobster catch rates (catch per trap-haul per set-over-day) for western Cape Cod Bay, 1981-1991.

Commercial legal catch rates for western Cape Cod Bay then rose to 0.72 in 1985 and 0.82 in 1986 (Figure 6). Record lobster landings were documented along the entire Massachusetts coast in 1985 and 1986 (Estrella and McKiernan 1986). Cape Cod Bay lobstermen had to contend with cooler spring temperatures again in 1987, and a 34% reduction in the coastal commercial landings resulted (Estrella and Cadrin 1988). The Bay legal catch rate declined markedly to 0.53 in 1987. Catch rates in the Bay were as follows: 0.75 in 1988, 0.53 in 1989, 0.63 in 1990 and 0.60 in 1991.

The upswing in the overall 1988 catch rate in Cape Cod Bay may well have been influenced by a more normal spring bottom water temperature regime. Actual commercial landings (in pounds of lobster) for all of Cape Cod Bay in 1989 increased 20% from the previous year, which suggests that the relatively low overall commercial CTH for western Cape Cod Bay in 1989 (Figure 6) may be a sampling artifact of the lobsterman sampled (Bruce Estrella, personal communication).

The mean legal catch rate in the discharge area declined from 1983-1987, thereafter stabilizing with the exception of an upswing in 1989. This trend contrasts somewhat with the commercial lobster catch rates (Figure 6) and landings for western Cape Cod Bay as discussed above. Annual legal CTH in our control area (Warren Cove) did not parallel these commercial data from 1983-1986, but did reflect a drop in 1987 and subsequent increase through 1989.

Our selection of reference quadrants changed during the time series of lobster data collections. The present reference quadrants, all located in Warren Cove, have been in use since 1984, during which time there have been only two years (1985 and 1990) of high plant operational status; in 1991 the plant was off-line for half the inshore lobstering season (May-July).

Impact area lobster catch rate data (not normally distributed) and plant thermal output were examined for a relationship using a nonparametric test for association, Kendall's coefficient of rank correlation (Sokal and Rohlf 1969). The association analysis utilized the mean Unit I thermal output for the period of May through November, which encompasses the inshore lobster fishing season, versus legal catch rates for the surveillance area during the full and partial on-line years (1973-1983, 1985, and 1990-1991). A nonsignificant Kendall's concordance of 0.440 ($P=0.58$) was found. Earlier in the study, we ran a parametric correlation test of the data from 1973-1983 and found a significant negative correlation ($P \leq 0.05$).

As to the limiting effect of current on catch rate, Auster (1985) reported that a water flow above a critical velocity (46 cm per sec) will retard the foraging behavior of lobster by inhibiting mobility. It is reasonable to expect there would be reduced trap catches in the immediate discharge area, where current velocity can reach over 2 meters per second (7 feet per second) at low tide. In fact, our diving observations have revealed few lobster in the immediate area of the discharge canal.

However, a direct cause and effect relationship between the thermal discharge current and the commercial lobster pot catch in the impact quadrats is difficult to substantiate because we have no control of fishing effort, including the location of traps fished. We have been investigating this relationship with our research lobster study, which is discussed later in this section. In 1988, with considerably more current (though at ambient temperature) emanating from the discharge canal than in 1987, the commercial catch rate of legal lobster remained unchanged in the surveillance area. In 1989, with seasonal thermal capacity at 36% and with one or both circulating water pumps operating, CTH in the impact area increased substantially. In 1990, with seasonal thermal capacity at 77% and both circulating pumps usually running, the impact catch rate declined. In 1991, with a seasonal thermal capacity of 37% and one pump running from May-July, the catch rate increased. These differences most likely reflect natural year-to-year variability in this area. Commercial gear sampled in the impact quadrats is often deployed at a distance far enough from the discharge canal that the effluent current is most likely not a major factor affecting lobster distribution and resultant catch.

In a continuing effort to standardize commercial lobster catch data with our experimental lobster data, the commercial legal lobster catch information in the discharge and surveillance areas were weighted by immersion time (days between pot-hauls) of the pots to generate catch per trap-haul per set-over-day (CTHSOD), a more accurate measure of catch per unit effort. In 1991, the legal CTHSOD increased slightly in the control area from 0.08 in 1990 to 0.12. Conversely, CTHSOD declined from 0.17 to 0.14 in the impact area.

Research Lobster Trap Fishing

Research lobster trap sampling was conducted for the sixth consecutive year (June through September, 1991). Our objective is to assess the impact of the operation of Pilgrim Station on the local lobster population. The following parameters have been examined: catch rates of legals and sublegals, size frequencies, sex ratios, culls (lobster with missing or regenerating claw(s)), and ovigerous (egg-carrying) females.

Table 2. Catch per unit effort[1] from research lobster gear in the Pilgrim area for 1991.

Area	Legal-sized Lobster (≥82.6 mm CL) CTHSOD	Legal-sized Lobster (≥82.6 mm CL) Mean ±2 Standard Errors	Sublegal Lobster (<82.6 mm CL) CTH	Sublegal Lobster (<82.6 mm CL) Mean ±2 Standard Errors
Discharge Area (Surveillance)	0.154	0.145-0.163	2.990	2.928-3.046
Rocky Point (Reference)	0.162	0.153-0.171	3.706	3.645-3.767
Priscilla Beach (Reference)	0.199	0.185-0.213	3.062	2.982-3.142

[1]CTH represents catch per trap haul; CTHSOD indicates catch per trap haul per set-over-day.

We sampled 9,682 lobster from 2,650 trap-hauls in the study area. Catch data for sublegal lobster overall, as measured by catch per trap haul (CTH), averaged 3.29, the same rate as in 1990. CTH for legals in 1991 declined from 0.41 (1990) to 0.36. When weighted by immersion time (days between pot-hauls) of the pots (CTHSOD), which is a more appropriate measure of catch per unit of effort for legal lobster, the overall catch rate fell slightly from 0.19 to 0.17 for the study area in 1991. The 1991 legal catch rates (Table 2, Figure 7) declined slightly at both reference sites (Priscilla Beach and Rocky Point) but decreased more at the impact site (Discharge). However, the catch rates of sublegals (Figure 8) were essentially unchanged from last year in all three areas.

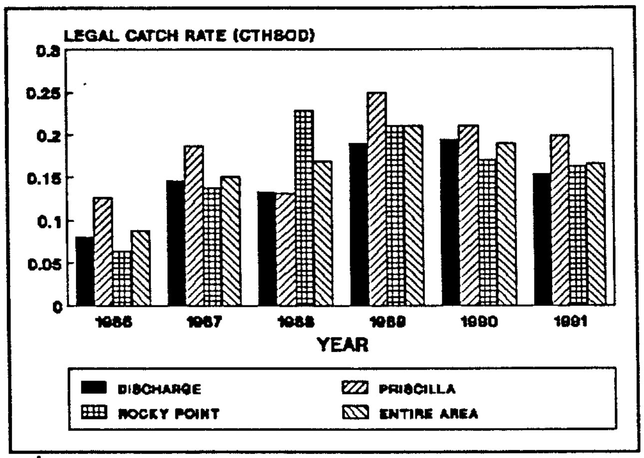


Figure 7. Legal lobster catch rates (CTHSOD) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1986-1991.

The overall study area sex ratio of males to females in the 1991 research catch was 1.3:1, similar to 1990 ratio of 1.2:1. The annual research lobster sex ratio has been relatively constant for the six year study off Pilgrim Station.

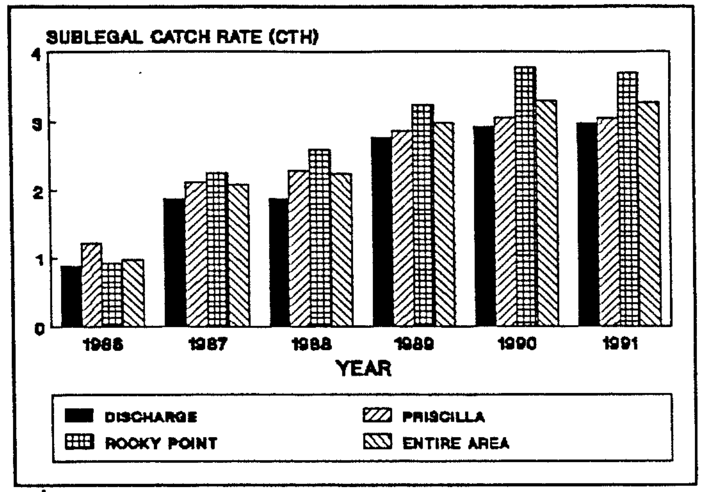


Figure 8. Sublegal lobster catch rates (CTH) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1986-1991.

The percentage of females ovigerous in the 1991 research catch was 1.5% (61 eggers), as compared to 1.2% last year. The percent females ovigerous was similar at each of the three sites. During the six-year study, no pattern in the distribution of ovigerous females has emerged amongst the sampling zones.

The percentage of culls in the research data increased from 27% in 1989 to 29% in 1990, where it remained in 1991. Over the six years, the cull rate has been lowest in the Discharge area. The rate was highest at Priscilla/White Horse Beach in 1986 and 1987, at Rocky Point in 1988, about equally high at both reference areas in 1989 and 1990, and highest at Rocky Point in 1991.

Initial analysis of 1991 legal CTHSOD and sublegal (CTH) lobster catch rates revealed the data was non-normally distributed which could not be satisfactorily corrected by transformation. Hence, nonparametric Kruskal-Wallis tests were performed, corresponding to the experimental design of a nested ANOVA (Sokal and Rohlf 1969), using the BMDP statistical software (BMDP

Statistical Software, Inc. 1990).

To test for differences amongst the three areas in 1991, legal catch rates were initially tested to ascertain if data across months within stations at a site could be pooled. We first had to insure we could statistically pool monthly catch data within a station, and only then would pooling of station data for an area be considered valid. At four of the ten stations (these all being at Rocky Point), the September legal catch rates were significantly greater than some or all of the other months (Figure 9). Therefore, higher level testing of catch rates by pooling stations and comparing areas was not undertaken.

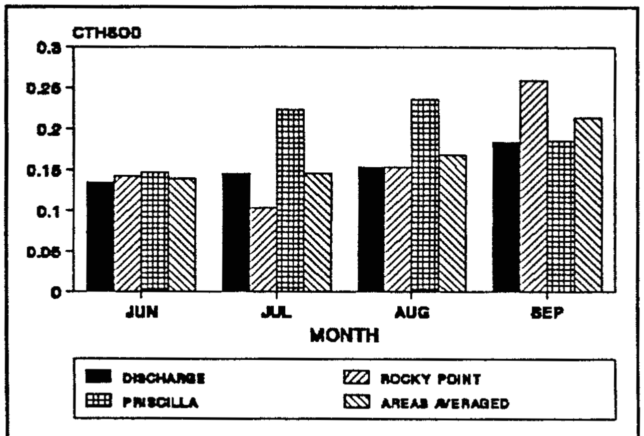


Figure 9. Monthly legal lobster catch rates (CTHSOD) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1991.

Data analyses subsequently changed from pooling months within stations to pooling stations within a site on a monthly basis, and then areas were contrasted on a monthly basis. As there were no significant differences ($P>0.05$) amongst monthly station data at any of the sites, station data were subsequently pooled monthly within each site. Monthly comparisons of legal catch rates amongst the three sites were performed using 1991 data. The legal catch rate off Priscilla Beach was significantly greater ($P\leq0.05$) than at both the Rocky Point and Discharge sites in July, while for September, the rate at Rocky Point was significantly greater ($P \leq 0.05$) than at the Discharge. A markedly lower catch rate in the Discharge may be related to the full operation of Pilgrim Station in September with a substantial amount of waste heat and current present.

Sublegal catch rates were analyzed using nested Kruskal-Wallis analyses across months, after initial analyses showed sublegal monthly catch data could not be pooled within a station. On the lower level monthly tests (within site by month) for June and July, there were sites with station(s) significantly different ($P \leq 0.05$) from each other, while in August and September, there were no significant differences amongst the stations within each of the areas. Hence, pooling of monthly sublegal catch rates was statistically questionable for June and July. After inspecting the data (Figure 10), we decided to make monthly areal comparisons of sublegal catch rates by month, with an attached statistical caution. There were no significant differences amongst the sites in June. In July, the Rocky Point sublegal catch rate was significantly greater ($P \geq 0.05$) than that at the other two sites, a pattern also observed in 1990. As in 1990, the sublegal catch rate at Rocky Point was significantly greater ($P \leq 0.05$) than the Discharge in August, while in September, the catch rate at

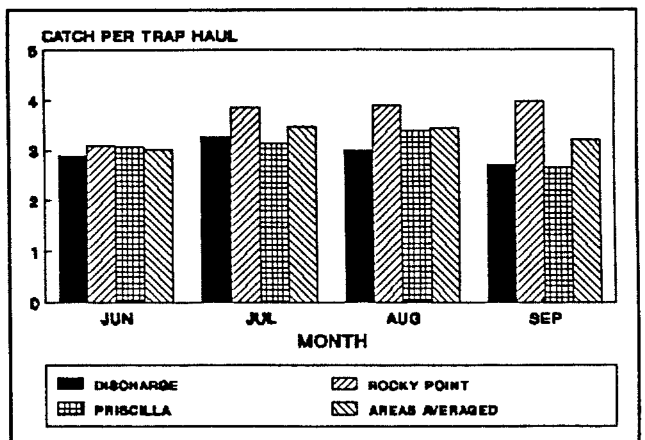


Figure 10. Monthly sublegal catch rates (CTH) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1991.

Rocky Point was significantly greater ($P \leq 0.001$) than at the other sites.

Analyses of sublegal catch data by month for the Discharge area revealed that Station H had the highest sublegal catch rate of all four discharge stations for every month. Stations E, F, and G had significantly lower ($P \leq 0.05$) sublegal catch rates than at Station H in June; while in July, the catch rate at Station G was significantly less ($P \leq 0.05$) than Station H. Stations F and G would most likely be affected by Pilgrim Station's thermal discharge, as they are closest to the discharge canal, while Station H would be least expected to be impacted (see Figure 2, Vol. 1). We measured the speed of the bottom discharge current at Station G to reach 69 cm per sec at low tide. This could impact the sublegal catch rate by reducing the mobility and maneuverability of small lobster (Auster 1985), thus shifting the small scale spatial distribution by size class in the discharge area. Howard and Nunny (1983) showed with the lobster, *Homarus gammarus*, that their distribution is limited by tidal current and wave action to low current areas on the bottom on a size selective basis.

This study provided us with an opportunity to examine for a relationship between lobster research catch data from the Discharge area and Pilgrim Station's thermal output (as an index of plant operational level) within a season. The nonparametric Kendall's coefficient of rank average correlation was performed on 1991 data. Average Unit I Pilgrim Station Capacity Factor (MDC Net %), calculated for those days when we fished pots in the discharge, was correlated with sublegal catch rates and then with legal catch rates per sampling day at each of the Discharge stations during the on-line period of mid-August through September. Data from the period June through mid-August were not used for this analysis, as the MDC Net % was zero.

There were no significant correlations between legal catch rates (CTHSOD) and plant MDC. However, significant negative correlations between sublegal catch rate and MDC were noted at Station F (P=0.004), Station G (P=0.007) and Station H (P=0.02). Due to the limited dataset available to use in this analysis, we must be cautious in our interpretation of the results. Catches at the adjacent control site at Priscilla Beach also fell from August to September. This may reflect a generalized local movement of lobster in the Priscilla/Discharge area. A possible inverse relationship between plant operation and sublegal catch rates at Stations F, G, and H is nonetheless interesting.

To summarize, sublegal catch in 1991 was shown to be typically lower at Station G than at the other discharge stations by Kruskal-Wallis statistical analysis. With only a partial dataset available, three of the four Discharge stations showed a potential inverse relationship between Pilgrim Station operational level and sublegal lobster catch rate.

There is another quantitative approach to ascertain Pilgrim Station impact. Limited to a single impact area (treatment) and having two reference areas, we used the extended outage (unstressed) period at the plant (1986-1988) to establish the relationship between areas, using the ratio of the biotic measure (catch rate) obtained at the discharge site (pooled for stations) to the average of the two reference sites (pooled station data). Future changes in the ratio during plant operation would be examined for impact on the local lobster population. This follows the methodology offered by Thomas and Van Voris (1986) for power plant environmental impact assessment. This procedure acknowledges the intrinsic 'impossibility' of finding identical reference locations, and therefore trend alterations in the resultant impact/reference ratios are monitored.

The grand mean ratio for legals was 0.826 and for sublegals, 0.819 for the three outage years, 1986-1988. For 1989, a transitional year in power operation, the ratio for legals equaled the three-year average, 0.826; whereas, the ratio for sublegals climbed to 0.910. For the full power year, 1990, the legal ratio increased to 1.021; the sublegal ratio was 0.857. For 1991, a summer of low power production, the ratio for legals was 0.856, with the sublegal ratio being 0.883. With additional year(s) of on-line data, we can compare the annual research lobster catch rates from the discharge (impact) area between on-line versus off-line periods. Additional data from high operational years are needed. As in 1989, we viewed 1991 as a low power generation year relative to the period - June through September - with plant output at 31%.

3. <u>Striped bass and Bluefish</u>

Background

Striped bass and bluefish are coastal, migratory, pelagic species that are highly prized by recreational and commercial fishermen. Both were among the top three gamefish sought by sport fishermen in Massachusetts (Massachusetts Division of Marine Fisheries 1977). Bluefish and bass have been the most sought after fish in the shore-based sportfishery at the Pilgrim Station Shorefront. The former led the sportfish catch and the latter ranked third at the Shorefront in 1991. We selected them as indicator species to assess impact of the thermal discharge at Pilgrim Station.

They are seasonally abundant in the outfall area as spring to fall migrants, with striped bass arriving inshore in Massachusetts in April and May and bluefish from May to June. Offshore migrations occur normally in October for bluefish and in November for bass. Both gamefish are voracious predators that are attracted to moving water, e.g., currents and tidal rips, where the velocity of the running water incapacitates smaller fish and invertebrates making them easy prey (Woolner and Lyman 1983). Ristori (1989) adds that most marine game species feed when there is a current running but cease this activity in slack water. Pilgrim Station's once through, open-cycle cooling system produces a continuously flowing, pump generated thermal current that can attract game fish to the outfall area.

Life Stages Impacted and Sampling Protocol

Realistically, the potential source of Pilgrim Station impact on striped bass and bluefish is from the discharge via thermal and current-induced effects. The thermal discharge can affect the juveniles and adults of both species in the receiving waters. Entrainment of their pelagic eggs and larvae is not a concern because neither spawns anywhere near the power plant. Impingement has not been a problem because both species are strong swimmers and generally can avoid plant impingement. Over the years, no bass and only four bluefish, all young-of-the-year ("snappers"), have been impinged at Pilgrim Station. Gill-net fishing, diving, and a creel survey provide data on bass and bluefish in the discharge and intake areas of the plant. Haul seining in the Plymouth area occasionally has produced catches of "snapper" bluefish.

Discharge and Sportfishing Related Effects

Discharge: thermal/current

Striped bass

Despite the precipitous decline in striped bass abundance along the Atlantic coast that began in the mid-1970's, the numbers of bass recorded in the Pilgrim area year to year clearly are related to plant operation (Table 3). Pilgrim Station's thermal discharge attracts, concentrates, and holds bass. When the power plant is operational and discharging a noticeable current of water, bass numbers are up off the plant; and conversely, when the station has been in an outage, low numbers have prevailed. Comparing the years, 1989-1991, in Table 3 illustrates this well. Furthermore, the pooled grand mean 5-panel gill-net catch rate of bass captured during the high operational years of 1983,1985, and 1990 was 88% higher than the grand mean for 1984,1986-1989 (outage or low output

Table 3. Striped bass recorded off Pilgrim Nuclear Power Station (PNPS) and plant operational capacity (MDC) for 1983-1991.

Year	PNPS MDC NET%	No. Observed by Divers	Sportfish Catch	Gill net Catch Rate
1983	80.3	24	150+	0.3
1984	0.1	0	0	0.0
1985	84.4	148	≈400	5.3
1986	17.5	10	0	0.3
1987	0.0	1	2	1.2
1988	0.0	0	3	0.7
1989	8.9	52	3	0.5
1990	72.3	481	150	7.1
1991	58.4	255	9	2.8

years. During 11 years of diving off the plant, 98% of the bass have been seen in the path of the discharge current. They generally occur in an aggregation, swimming near the bottom up into the discharge canal and back out for about 20-30 m in a presumed search pattern.

A second effect of the waste-heat discharge is the exclusion zone to striped bass that occurs in the better part of the thermal plume at Pilgrim Station in August and perhaps part of September because of high water temperatures. The surface temperature usually peaks in August, and the bottom temperature, in September. A surface temperature of 22.7°C has been obtained in August out as far as 0.8 km offshore of the power plant. We recorded bottom temperatures of up to 32°C in August and September of 1990 and 1991 at the mouth of the discharge canal. At 60 m offshore of the canal in the thermal plume, bottom temperatures of 22°-25°C were obtained at the same time of year in 1990 (high operational year).

Catches and sightings of bass are at their lowest in the discharge area in August. They are especially active at water temperatures between 7° and 21° C (Smith and Wells 1977). The water temperature preferred by striped bass changes with age, with the juvenile and adult life stages having different environmental requirements - in particular, the need of larger fish for cool water (Coutant 1985). A summer habitat suitable for adults has water temperatures between about 18° and 25° C. The thermal tolerance for adult bass is $\leq$ 25°C; temperatures above this are harmful and will be avoided. Prolonged exposure to temperatures above 27°C is most likely lethal to bass (Smith and Wells 1977).

<u>Bluefish</u>

The first bluefish caught in the Pilgrim area traditionally are taking in June in the thermal plume. Lund and Maltezos (1970) reported that bluefish migrate inshore when the water warms to 12°-15°C and seldom are abundant below these temperatures. The earliest bottom temperature record we have of bluefish occurring in the Pilgrim area is 15°C.

The thermal elevation of the cooling water has delayed the emigration of bluefish from the outfall area. Normally absent from the inshore waters of western Cape Cod Bay by October, when the water temperature falls to about 13° to 15° C, bluefish were still being caught by anglers in the thermal discharge when the shorefront closed at the end of November 1985. At the time, we obtained temperature measurements in the thermal plume of 10°C (bottom) and 17°C (surface). Adult bluefish can survive temporarily down to at least 7.5°C (Lund and Maltezos 1970) but will avoid temperatures of 10°C and below, if possible.

According to Olla and Studholme (1971), the preferred temperature range of bluefish is 19° - 22°C; the optimum is 20°C. With an upper avoidance temperature of 29°C (Wilk 1977), bluefish would be excluded from part of the discharge area in August when the waste water can exceed 30°C. Diver observations and gill-net catches support this contention.

Pilgrim Station's discharge attracts bluefish mainly because of the current. Lyman (1974) reported that bluefish are drawn to moving water (rips, currents, etc). Bluefish often rise to the surface at dawn to feed and will continue to do so until satiated or until the tidal current slackens or light intensity increases (Lund and Maltezos 1970). On foggy days, bluefish found in rips often feed near the surface until the current goes slack.

When the power plant is operating, a continuous current of water is discharged. On many occasions, we have seen bluefish 'breaking' for hours at the surface in and on the edge of the thermal plume. That bluefish concentrate in the outfall is substantiated by our sampling programs. The number of bluefish recorded is generally low in the Pilgrim area when the plant is not operating or only discharging a low-velocity current, but conversely, is relatively high with the plant fully operational. Despite the coastwide decline in commercial and recreational catches of bluefish throughout the 1980's (Northeast Fisheries

Center 1989), the pooled grand mean gill-net catch rate of bluefish off Pilgrim Station for 1983,1985, and 1990 (high output years) was 45% higher than the overall mean for 1984, 1986-1989 (outage, low output years).

Bluefish were seen by our divers off the plant in 1983 and 1989-1991 (years of at least partial station operation). Divers sighted no bluefish, however, during the outage years, 1984 and 1986-1988. Ninety-one percent of the bluefish visually were observed in the 'denuded' zone as compared to the 'stunted' or 'control' zones. Our diving index of bluefish relative abundance in the immediate discharge area (i.e., observed fish per dive) increased from 1.5 in 1989 (low plant output - 28.9% of capacity) to 21.0 in 1990 (high operational year- 72.3%), and than declined somewhat in 1991 (58.4% plant output) to 15.6. Bluefish typically aggregated in the upper water column and were seen swimming in an elongated oval pattern from the terminus of the discharge jetties out to about 60 m off the discharge canal.

There is a direct link between station operation and the sportfish catch of bluefish. The presence or absence of a strong thermal discharge current at Pilgrim Station results in good or poor sportfish catches, respectively, in the outfall area. Creel surveys at the Pilgrim Shorefront revealed that an estimated 1,000 bluefish were landed by anglers off the plant in 1983, and 2,200, in 1985. Both were years of high plant output (>80% thermal capacity with two circulating seawater pumps operating). Conversely, with little waste heat and a marked reduction in discharge flow during the summer and fall fishing seasons of 1984, 1986-1988 (outages), the catches of bluefish totalled under 100 fish for the four years.

During the attenuated July-August creel survey of 1989 (transitional year in power production), the catch slightly improved with 68 bluefish reported. Whereas, for the May-August surveys of 1990 (high operational year) and 1991 (moderate operational year), the recreational catch for these months was about 950 bluefish for the two years combined.

Sportfishing Effects

Bluefish and striped bass have ranked second and fourth, respectively, in recreational catches over the years at the Pilgrim Shorefront. In fact, bluefish ranked first the last few years. The thermal discharge at Pilgrim Station alters the small scale distributions of bass and bluefish in the Pilgrim area. This has a positive effect on the sport fishery off Rocky Point because numbers of both species mass for a time at a known location within casting distance from shore.

However, on the negative side, this attraction of both species to the outflow results in increased densities which greatly increase vulnerability to human exploitation and the potential to be stressed by heat or cold shock and gas supersaturation. This can lead to a substantial increase in the exploitation rate. Sport fishing can comprise a sizable part of fishing mortality for some game fish (Williams et al. 1983). For example, the sportfish catch of bass and bluefish has exceeded 600 fish and 2,000 fish, respectively, at the Pilgrim Shorefront in a given year.

4. Atlantic silverside

Background

The Atlantic silverside is an abundant schooling forage fish ranging from New Brunswick to Florida which typically inhabits shallow marine and estuarine waters. Silversides mature at age one, with only a small percent of the population surviving to two years of age. Spawning in the Massachusetts Bay area occurs from late April through June in estuarine locations. The adhesive eggs attach to mats of filamentous algae at the high tide mark (Conover and Kynard 1984).

As inshore water temperatures decline below 6° C, most adult silversides in New England waters undergo a late fall offshore migration to overwinter in waters as deep as 50 m on the continental shelf (Conover and Murawski 1982). Conover and Ross (1982) estimated overwintering mortality of Massachusetts silversides to be 88% south of Cape Cod and 97% north of the Cape. The number of adults returning to inshore waters in the spring (spawning stock) appears to remain relatively constant regardless of the previous fall population size, as fish from less abundant year-classes exhibit lower winter mortality than dominant year-classes presumably because of their larger mean body size.

Silverside abundance in the Plymouth area is greatest in summer and early fall. The local population likely spawns in nearby Plymouth-Kingston-Duxbury Bay estuary. Juveniles and adults can be affected by the thermal discharge and by impingement on Pilgrim Station's traveling screens.

Gear Types and Life Stages Affected

Any likely impact of Pilgrim Station on the Atlantic silverside population would be due to impingement. Silverside eggs are rarely entrained at Pilgrim Station, and larval entrainment has been relatively light during the years of plant operation. We have haul seined juvenile and adult silversides in the Intake which are potentially subject to impingement. The data collected at established seining stations provide an index of abundance of the local silverside population. Gill net and trawl fishing have captured only low numbers of silversides.

Review of Impingement and Entrainment Effects

Silverside egg and larval entrainment is low at Pilgrim Station. Entrainment samples collected at Pilgrim Station by Marine Research, Inc. from 1980 to 1991 show a low incidence of silverside larvae (Marine Research Inc. 1990; see Entrainment Monitoring, this Volume).

Conservative estimates of annual equivalent adult silverside losses from Pilgrim Station operation, based on fecundity and egg survival estimates, are 187,000 fish per year by impingement and 8,000 fish per year by entrainment, for a total of 195,000 individuals from the local population (Stone and Webster 1975). Such a speculative loss appears large, but based on the prolific nature and abundance of the species (26,155 captured by seine in 1991 alone) the effect on the population is questionable.

Discharge Related Effects

Based on silverside temperature tolerance data and the predicted thermal plume at Pilgrim Station, it was projected that adult silversides would be excluded from a 4.5 X 10^4 m^2 site in the discharge area in summer (Stone and Webster 1975). The effects of the thermal plume are probably of little consequence to Atlantic silversides due to their high abundance in the region, the relatively small size of the thermal exclusion zone, and the species' ability to move to avoid stressful temperatures.

Intake Related Effects

In 1991, Atlantic silverside comprised 46% of the haul seine catch at all sites combined. At the Intake, the silverside ranked second in seine catch abundance, only exceeded by Atlantic herring - most of which were captured in June. This is the usual pattern in the seasonality of seine data, as the Intake catch typically includes, depending on the year, large catches of clupeids and/or sand lance. The annual silverside catch rate for all stations pooled nearly doubled from 216 fish per set in 1990 to 422 in 1991. The silverside catch rate for 1991 in the Intake was similar to last year's value. The catch rate at Long Point showed a pronounced increase while the two remaining sites (Warren Cove and Manomet Point) had declining catches (Figure 11).

Seine data collected over the past decade show that the Atlantic silverside is the dominant species sampled at all stations, typically comprising well over 80% of the annual seine catch (Lawton et al. 1990). In the Intake, haul seine catches of silversides for the June through November sampling period consistently have shown a dearth in abundance of this species in June, high numbers from July through September, followed by a subsequent decline.

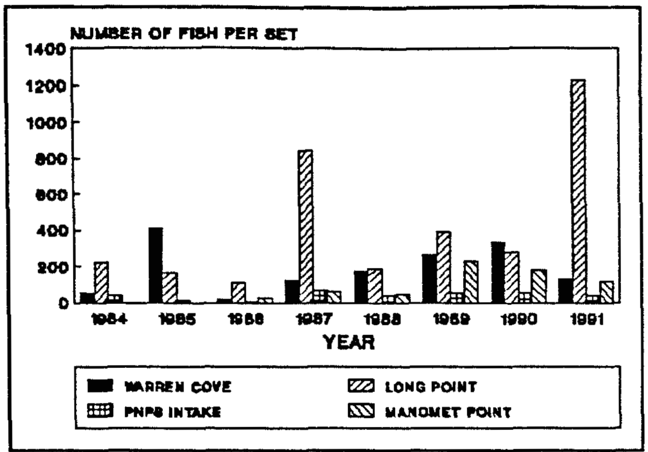


Figure 11. Mean catch per standard haul seine set of Atlantic silverside collected along the Plymouth shorelines of western Cape Cod Bay, 1984-1991.

Pilgrim Station impingement data have consistently documented the silverside as a dominant species impinged. Silverside impingement is highest during the colder months of the year, November through April (Lawton, Anderson et al. 1984; Marine Research Inc. 1990). In 1991, 275 silversides were sampled in impingement collections at the station. The monthly mean size of silversides impinged ranged from 9 to 11 cm total length. These are adult fish which most likely overwinter in the Intake embayment. Conditions in the deeper water of the Intake channel are apparently adequate for silverside survival during the winter. It is during the time of peak silverside abundance during the summer that silverside impingement is nearly nonexistent at Pilgrim Station. Conversely, silverside impingement peaks in winter when their numbers inshore are low. Perhaps reduced mobility of the overwintering fish because of cold temperature stress makes them more susceptible to impingement.

5. Atlantic menhaden

Background

The Atlantic menhaden is a pelagic, migratory species considered to comprise a single population. Ranging from Nova Scotia to Florida, menhaden spawn on the continental shelf and in large bays (Bigelow and Schroeder 1953). Off New England, spawning occurs from spring through fall, with a peak in June or July (Scherer 1984). The larvae hatch from buoyant eggs and soon move well up into low-salinity waters of estuaries (Young 1974). Juveniles school together, eventually moving to higher saline waters of an estuary, where they remain until declining water temperatures trigger a coastal migration southward to offshore wintering grounds off the southeast Atlantic coast. During spring, there is a return migration northward; individuals summer along the coast by latitude according to age/size (Nicholson 1978). Schools of menhaden arrive off Massachusetts in April as coastal waters warm above 10° C. Menhaden older than two years travel further north, with few three year-olds occurring south of New Jersey.

Atlantic menhaden are extensively fished commercially along the Atlantic coast. In the 1950's, the menhaden population was comprised primarily of three to eight year-olds, but with increased fishing mortality in the 1960's, fish under three years of age constituted the majority of the coastal stock. A few strong year-classes recruited to the population in the 1970's, which are in evidence in our gill-net catch data (Figure 12).

The United States Environmental Protection Agency and the

Massachusetts Division of Water Pollution Control selected Atlantic menhaden as a Representative Important Species (RIS) to assess impact of Pilgrim Station (Stone and Webster 1975). As menhaden are sensitive to environmental stressors resulting from environmental intervention, Young (1974) provided specific examples of detrimental impacts of coastal power plants on the species.

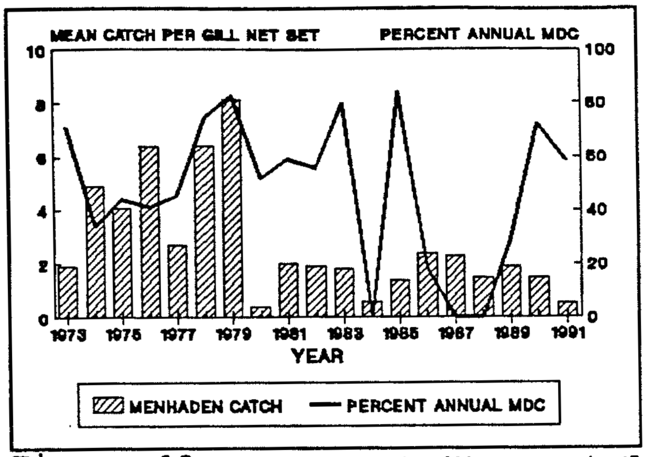


Figure 12. Mean annual gill-net catch (5 panels) of Atlantic menhaden and annual MDC operational level at Pilgrim Station, 1973-1991.

Life Stages Impacted and Sampling Protocol

Impacts of Pilgrim Station on Atlantic menhaden would most likely result from impingement of adults and juveniles, egg and larval entrainment, and gas bubble disease (GBD) of adults in the thermal discharge. We have sampled juvenile menhaden in the Intake embayment by haul seining; these fish are susceptible to impingement on Pilgrim Station's intake travelling screens. Impingement and gill-net sampling have captured both adult and juvenile menhaden. Fish overflights are done to monitor the inshore western sector of Cape Cod Bay for large schools of fishes such as menhaden which may enter the Pilgrim area. In June 1991, a school of about 300,000 adult menhaden was spotted on an overflight in the vicinity of Pilgrim Station.

Review of Impingement and Entrainment Effects

Atlantic menhaden spawn in Cape Cod Bay (Scherer 1984).

Menhaden eggs and larvae have been sampled at relatively low densities. The buoyant eggs are found from April through November, while the larvae occur from April-December.

The actual entrainment of menhaden eggs at Pilgrim Station has been relatively low, with the exception of 1982. Larval entrainment is uncommon. In 1991, eggs were entrained in May, June, and September.

Impingement of menhaden on the intake screens at Pilgrim Station generally has been of juveniles. In 1991, 113 menhaden (size range 52-131 mm TL) were sampled in impingement collections from August-December, corresponding to the time juveniles leave estuarine nursery grounds. Menhaden ranked first in impingement collections in September and second in December.

Haul seine catches from the intake since 1981 have included large numbers of young clupeids (menhaden/river herring) between September and November of some years; these fish are subject to impingement. In 1990 and 1991, however, menhaden were not seined in the intake.

Stone and Webster (1975) predicted, via a Ricker stock and recruitment model that losses to the menhaden population from entrainment and impingement at Pilgrim Station are negligible.

<u>Discharge Related Effects</u>

The annual gill-net catch data from 1971-1991 for adult menhaden show depressed catch rates since 1980 (Figure 12), when the lowest catch rate was obtained. The rate in 1991 was the second lowest of the time-series. A plot of operational status and annual mean menhaden gill-net catch does not suggest a relationship between these variables (Figure 12).

The thermal tolerance temperature for juvenile menhaden is ≤ 33° C (Young 1974), while adults acclimated to 15° C tolerated temperatures up to 31° C (Stone and Webster 1975). The preferred temperature range for adult menhaden is 10-21° C (Stone and Webster, personal communication). Spring migrating menhaden, on occasion, have been attracted to the Pilgrim Station thermal discharge because the outfall temperatures are within their preferred range when compared to ambient. Summer and early fall discharge temperatures exceed the menhaden's preferred range, thus minimizing the species attraction to the thermal effluent at these times.

However, mortalities have occurred at Pilgrim Station. In August 1978, over 2,000 juvenile clupeids (including menhaden) died in the thermal plume at Pilgrim Station because of thermal stress perhaps aggravated by chlorine. Cooling waters from power generating stations also can become supersaturated with dissolved gases. Fish residing too long in supersaturated water can develop gas bubble disease (GBD), where emboli form in the blood and other tissues causing blockage, rupture, and even death. Mortalities occurred to adult menhaden that were residing in the Pilgrim discharge canal in April of 1973 and 1975; GBD was the causative agent (Lawton et al. 1986).

Dissolved gas saturations in the Pilgrim thermal discharge are highest in spring and early summer concomitant with increasing ambient water temperatures and decreasing gas solubility. In particular, potentially GBD causing dissolved nitrogen saturations ($\geq$115%) occur in the cooling water at Pilgrim Station during the menhaden's inshore stay of April-November. A fish barrier net was placed in the discharge canal in the fall of 1973 to prevent fish access to the top two-thirds of the canal. It was hoped this would limit the potential for future GBD incidents. No large concentrations of adult menhaden have occurred in the discharge canal or thermal plume for any period of time since. However, in August 1985, an estimated 300 juvenile menhaden, located in the lower end of the canal, were afflicted with GBD; no mortalities were documented.

Stock-recruit relation modeling of the population, incorporating GBD mortalities at Pilgrim Station, forecasted a negligible impact of the plant on menhaden (Stone and Webster 1975).

6. Winter Flounder

Background

A familiar resident of bays and estuaries along the Northwest Atlantic coast from Labrador to Georgia, the winter flounder has been described as the most common shoal water flatfish found in the Gulf of Maine (Bigelow and Schroeder 1953). Winter flounder exhibit localized seasonal onshore-offshore migrations (McCracken 1963), and the coast-wide population is considered to be comprised "of many independent localized stocks" (Perlmutter 1947). In the

Plate 5. Bottom trawl being set to sample groundfish in the inshore waters of western Cape Cod Bay. Catches are used to measure potential impacts of Pilgrim Station on the benthic fish community.

Plate 6. Typical trawl catch is processed which includes identifying enumerating, and measuring the different species for environmental assessment. Catches of winter flounder have been consistently largest at the Pilgrim Station intake trawl station.

and early spring (Bigelow and Schroeder 1953), winter flounder spawn demersal, adhesive eggs (unlike those of other local flatfishes), that often clump together on the bottom (Breder 1924) in association with filamentous diatoms (Klein-MacPhee 1990). The free-swimming larvae also remain near the bottom while gradually undergoing metamorphosis to the adult form. Juveniles remain in or near shallow natal waters for most of their first two years, moving primarily in response to extremes of heat or cold (Buckley 1982).

A review of long-term entrainment data revealed that low numbers of winter flounder eggs and larvae have been entrained at Pilgrim Station (Marine Research, Inc. 1991), a pattern which continued in 1991 (Marine Research, Inc., this report). As such, entrainment of flounder eggs and larvae does not pose much of a threat to their overall abundance in the Pilgrim area.

<u>Impingement</u>

With their affinity for sheltered estuaries and embayments (Bigelow and Schroeder 1953; Pearcy 1962), juvenile and adult flounder are commonly found in Pilgrim's Intake embayment (Lawton et al. (1990), and it is no surprise that they are one of the more commonly impinged fish (Anderson 1990). However, review of the impingement data collected at Pilgrim Station from 1981 to 1991 reveals that only 343 winter flounder were actually collected. Clearly, coast-wide fishing mortality (NEFC 1991) must be having a greater impact on the local stock than both entrainment and impingement.

Discharge and Sportfish Related Effects

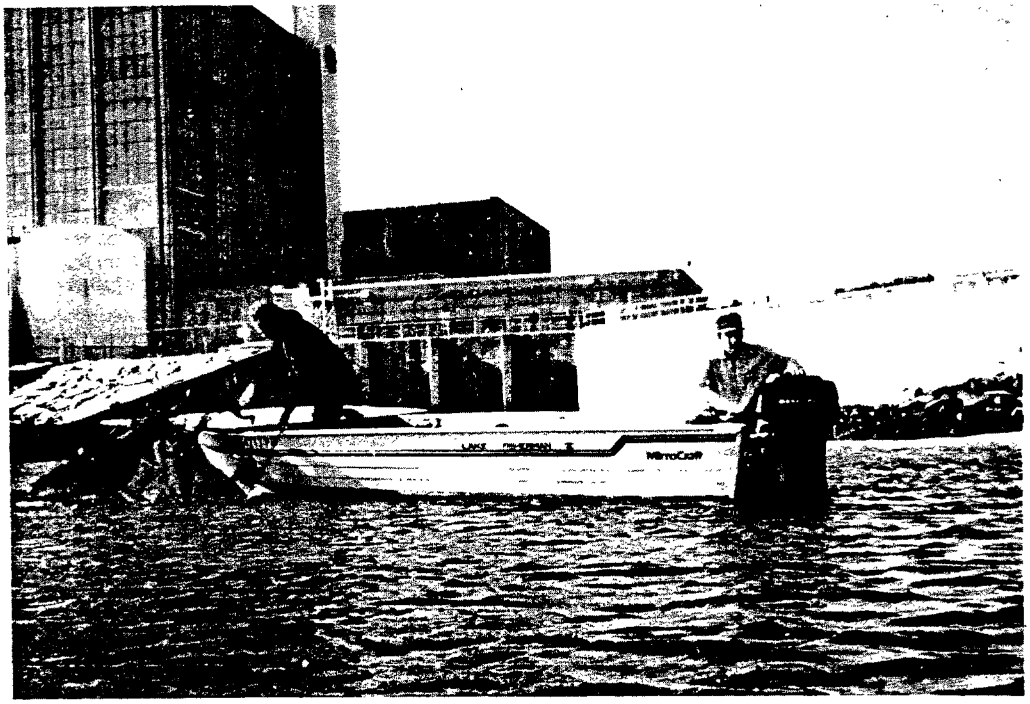


Plate 7. Haul seining in the intake embayment at Pilgrim Station: the net is being set from a powered-skiff to enclose a rectangular area. Seine catches can be integrated with impingement data for a more comprehensive evaluation of potential impact on shorezone fishes.

Plate 8. Haul seine catch processed on the beach near the Pilgrim Station intake (fish are enumerated and measured). Among the shorezone fishes are important forage fish such as the Atlantic silverside and sand lance, and the juvenile stages of several commercial species such as the winter flounder and Atlantic menhaden.

in the region extending from south of Cape Cod to the Delaware Capes (Clayton et al. 1978). In the Plymouth area, Bigelow and Schroeder (1953) reported the most productive grounds to be the rocky areas around Manomet Point and the Gurnet.

Characteristic of Labrids, tautog are structure oriented and generally found in association with reefs, wrecks, ledges, or jetties. Affording shelter during nocturnal torpor (Olla et al. 1974), such structures also are a productive source of food, hosting a profusion of attached and mobile invertebrates such as blue mussels (*Mytilus edulis*), lobster (*Homarus americanus*) and green crabs (*Carcinus maenas*). Blue mussels are a primary food of tautog, although they will eat other invertebrates. The adults leave shelter to feed during the day, occasionally ranging as far as 500 m (Olla et al. 1974), but return at night. Bigelow and Schroeder (1953) reported that tautog will follow a flood tide up above the low water mark to feed in the intertidal zone, dropping back on the ebb. When not feeding, adults have been observed by us to gather in a hole and lie on the bottom unless disturbed. Juvenile tautog, which associate closely with a particular structure during the first 3 years of life (Olla and Studholme 1975), generally range no more than 2-3 m during feeding. Proximity to shelter can serve as protection from predators. Olla et al. (1974) observed a group of juvenile tautog (≤ 25 cm) being chased by three striped bass inside the Fire Island Coast Guard Basin. The tautog remained within 1 m of the breakwater while feeding and were able to escape the bass by moving into the deeper crevices between the rocks.

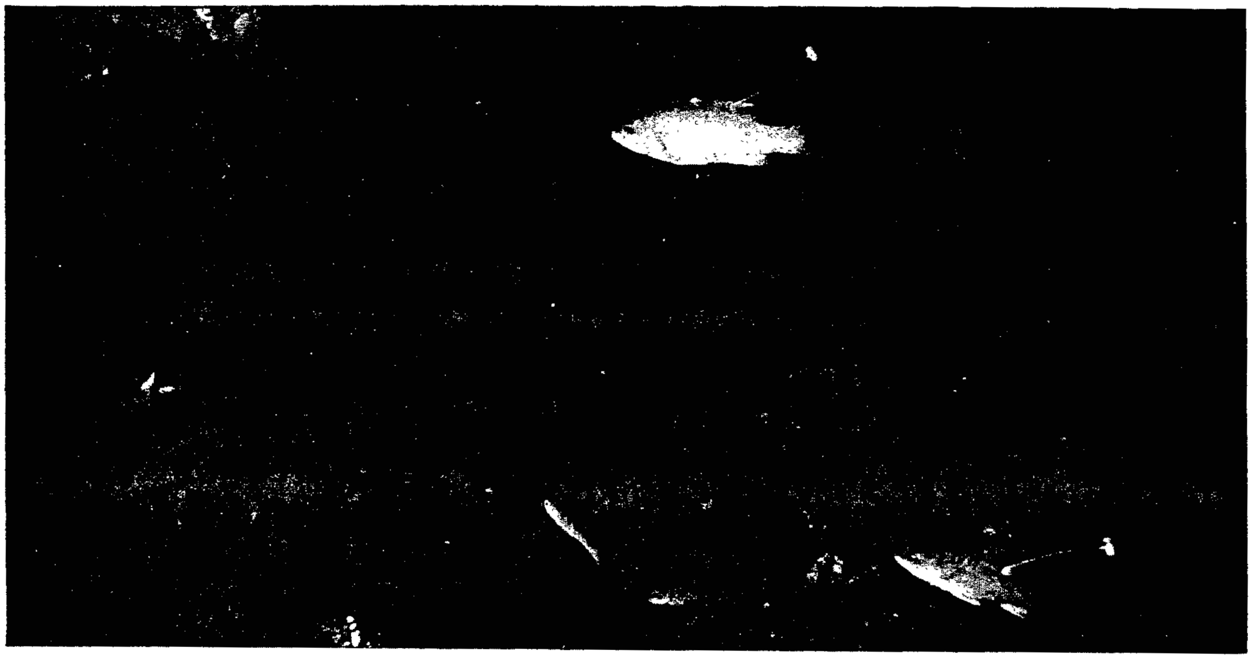


Plate 9. Tagged cunner seen swimming off the seaward side of the outer intake breakwater at Pilgrim Station. Diving observations have recorded the greatest number of fish sighted off Pilgrim Station to be cunner, which are structure oriented.

Plate 10. A winter flounder on the bottom near diving Station D_1 (~ 50 m, seaward of the discharge canal) in the "denuded" zone off Pilgrim Station. An important commercial and recreational fish, flounder inhabit the Pilgrim area throughout the year and have been used as an "indicator" species to assess stress imposed by the release of the heated effluent.

abundant as cunner, tautog are observed regularly around the outer intake breakwater and discharge canal jetties. Project divers report that on a flood tide, tautog are often found at the mouth of the discharge canal. The large boulders forming the discharge jetties provide cover and substrate for beds of blue mussels. The attractiveness of this area to tautog creates the potential for plant impact. Olla and Studholme (1975) and Olla et al. (1979) demonstrated in the laboratory that juvenile tautog will remain in their shelter even if thermally stressed. As temperatures approached the upper tolerance limit, young tautog became less active and began to enter a torpid state, reminiscent of night-time behavior.

Tautog have limited commercial value north of Cape Cod, because of the discrete localized populations and limited consumer demand. However, they are an important gamefish and excellent table fish.

Because of its local occurrence, importance as a gamefish, and potential for plant impact, we selected tautog as an indicator species.

Life Stages Impacted and Sampling Protocol

We have identified aspects of plant operation that constitute potential sources of impact to tautog (Table 1). The measurement of impact of the operation of Pilgrim Station can be confounded by other impacts from a number of sources. Bay-wide environmental conditions such as water temperature can affect spawning, as well as the survival of eggs and larvae. Bigelow and Schroeder (1953)

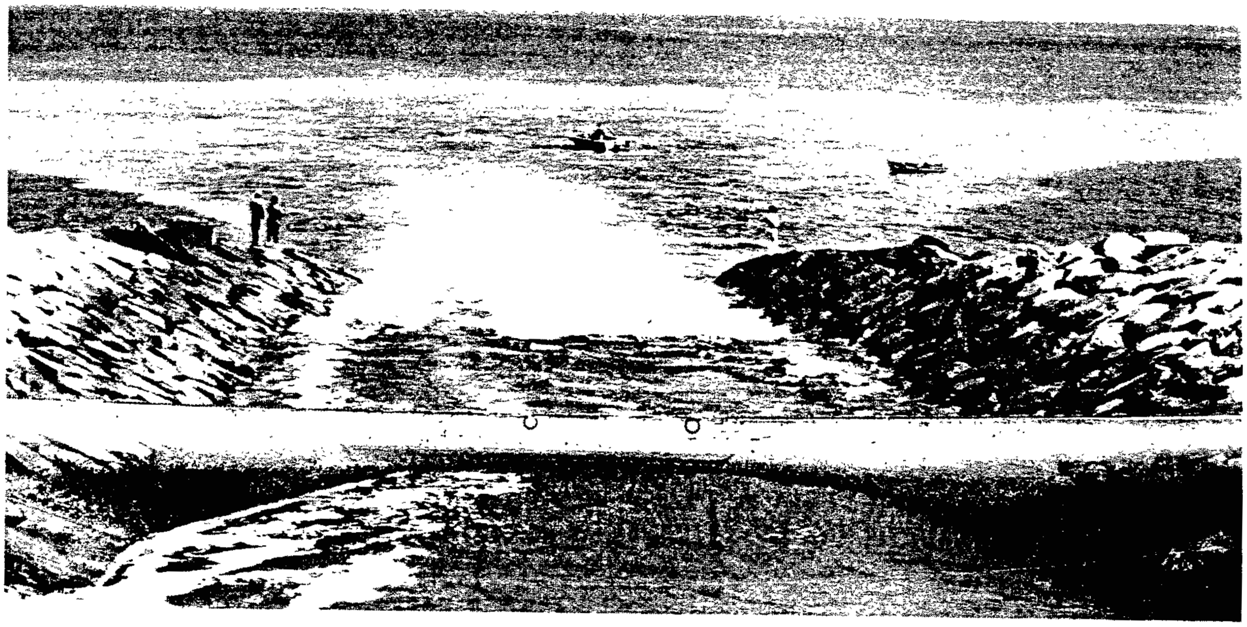


Plate 11. Pictured is the thermal effluent discharging into Cape Cod Bay, and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background as the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

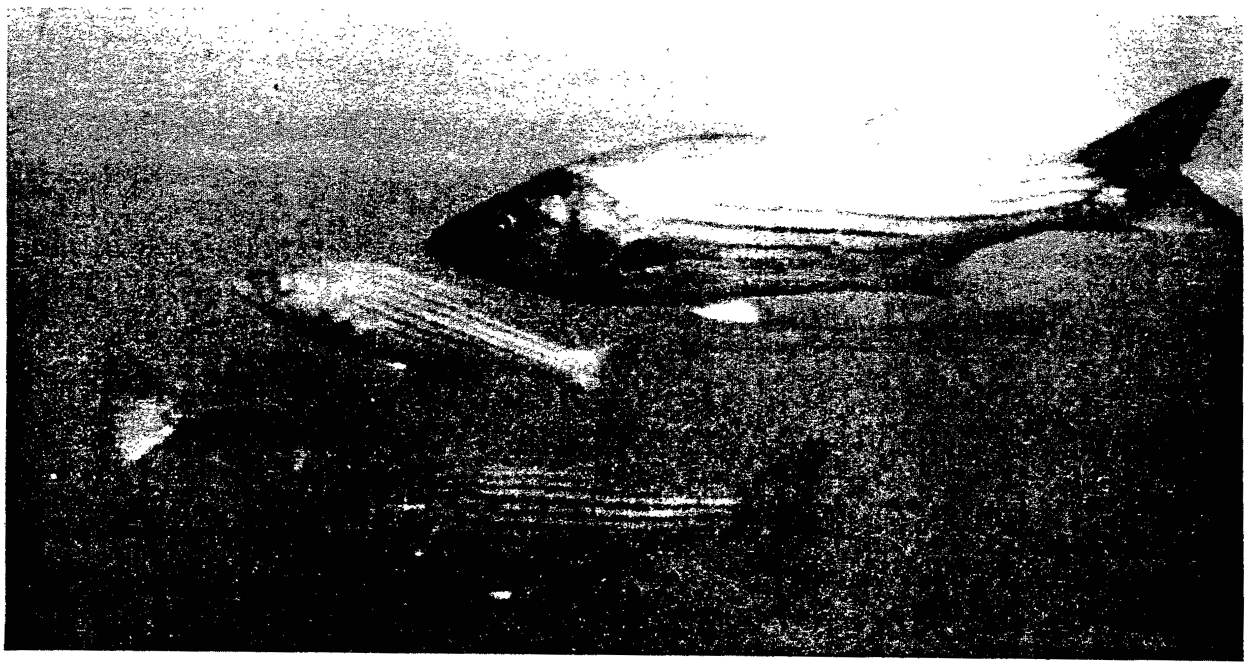


Plate 12. Striped bass aggregate in the thermal discharge current at Pilgrim Station, often swimming just off the bottom into and out of the discharge canal. Bass are attracted to moving water as a feeding ground.

form of impact. Interestingly, most of the tautog impingement occurred in late fall, usually December. Possibly these fish initiated the search for winter shelter late and swam into the intake channel seeking deeper water, but ended up entrapped on the screens.

Discharge, Intake, and Sportfish Related Effects

Discharge: Thermal/Current

Using project temperature data and findings from thermal tolerance and behavior studies conducted in the laboratory by Olla and Studholme (1975) and Olla et al. (1978), we would assume that the temperature of the discharge waters, even at peak output at the time of highest ambient temperatures, will not induce overt mortality of tautog. The fish, however, would be distressed and may exhibit behavioral changes, such as, reduced activity and decreased aggression and spacing among the adults. There would be a tendency for the juveniles to seek shelter. The latter are especially vulnerable because, when stressed, they will not leave their shelter even to the point of death (Olla and Studholme 1975).

During observational dives in the discharge area (flood tide), we have observed adult tautog moving into and out of the mouth of the discharge canal, while some were sheltering in the rocks of the jetties. Few juveniles have been sighted in the path of the thermal plume, although some have been seen in the control area south of the discharge. On a few of these dives, we measured bottom temperatures in excess of 30° C at the mouth of the discharge canal. We did not observe any tautog mortality. Tautog, most likely, are attracted to the discharge area by the dense growth of blue mussels, moving into the canal mouth on incoming tide and out on the ebb. While in the thermal effluent during late summer, these fish are probably stressed. Their schooling and sheltering behavior suggest this. However, they apparently tolerate the heat to feed. Some relief can be found in an area of cooler water caused by a counter-current that sets up just inside the seaward end of the southern-most discharge jetty, where our divers often have observed tautog grouped there. At low tide, the velocity of the discharge current and shallow depth preclude tautog movement into the area. It is doubtful that adult fish seek shelter in the rocks of the discharge jetties at night because of the extreme variation in depth caused by tidal amplitude.

The low number of juvenile tautog sighted by divers suggests that fish this size are not associating with the boulders that form the discharge canal. In addition to the strong current, the discharge may be too far from their natal area for the young to be found there in abundance.

Regarding their occurrence in the Pilgrim area, project gill-net and observational dive data show wide fluctuations in relative abundance over time. Graphing plant output (% MDC, i.e., thermal capacity) for the spring and summer seasons, when tautog are found inshore, versus gill-net catch rates for tautog over the years (Figure 14) does not suggest any relationship.

Intake Related Effects

With the exception of impingement, we have found no impact to tautog within the intake embayment.

Sportfishing

Tautog are held in regard as a gamefish as they are considered a good fighter on rod and reel and good to eat. South of Cape Cod and into Rhode Island waters, tautog are sought where there is structure, such as wrecks, ledges, and piers. North of the Cape, they are also popular but are less abundant. Off the Pilgrim Shorefront, tautog have been captured by shore-based anglers but not in great numbers. We believe this is due both to a small local population and the limited amount of effort directed at tautog. Tautog most often are found in the discharge canal, and most anglers in that area are targeting striped bass and bluefish. Mortality induced by recreational fishing is therefore not considered to impact the local tautog population.

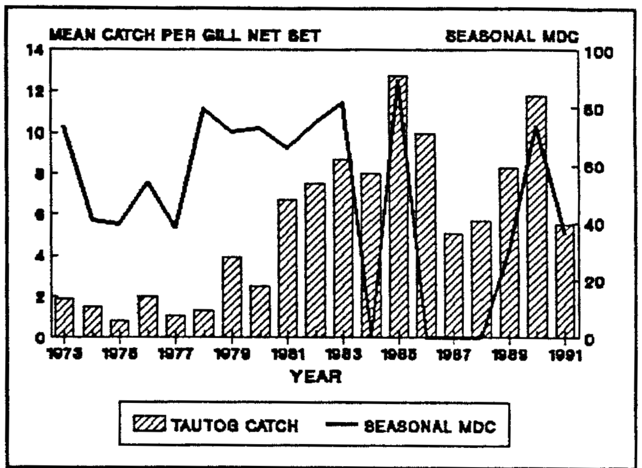


Figure 14. Mean annual 5-panel gill-net catch of tautog and annual % MDC operational level at Pilgrim Station, 1973-1991.

IV. IMPACT PERSPECTIVE

We have selected eight target species to assess Pilgrim Station impact on marine biota. The American lobster and winter flounder are benthic residents in the Pilgrim area, supporting important commercial and recreational fisheries. The predatory bluefish and striped bass are seasonally abundant off the power station's discharge and are highly prized by sport fishermen in the area. The pelagic schooling Atlantic menhaden is commercially harvested by purse seiners. This species was involved in two major documented incidents of gas bubble disease in the thermal discharge at Pilgrim Station. The Atlantic silverside is the most abundant fish in the Pilgrim area and is an important prey organism. A resident groundfish, cunner abundantly populate the immediate vicinity of the breakwaters and discharge jetties at Pilgrim Station during the warmer months. The tautog is a groundfish that resides near rock structure off Pilgrim Station, commonly seen by divers and caught by sport fishermen in the area.

To date off the Power Station, which has a relatively low historical operational record (47%), there have been abiotic changes (e.g., local thermal loading and scouring) and resultant biotic perturbations (e.g., population reductions and shifts in a species' spatial distribution because of avoidance or attraction); however, these have been localized or occasional events.

V. CONCLUSIONS

Cunner

1. We captured ripe cunner seaward of the outer intake breakwater at Pilgrim Station in May which suggests there is local spawning. Cunner eggs and larvae were entrained from May through September in 1991. Large numbers of fish eggs and larvae are entrained at Pilgrim Station, and a high percentage of these are cunner, e.g., 33% in 1991.

2. Cunner led the impingement collection in May 1991 at Pilgrim Station.

3. Over the past seven years (1985-1991), the catch rate of cunner, using a gill net, has declined by about 70% from the previous eight years. The 1990 and 1991 catch rates are the lowest of the time series.

4. Because of stressful warm temperatures, cunner avoid the discharge canal and near-thermal plume during late summer.

5. The discharge current at the station is of sufficient velocity to shift the small scale distribution of cunner by size class, with larger cunner attracted to the discharge current on a flood tide.

6. Cunner ranked second in the sportfish catch off Pilgrim Station in 1991. Most are left to die after being caught by anglers at the Shorefront.

7. The cumulative effects of entrainment, impingement, and sportfishing have contributed to a reduction in the local cunner population.

American Lobster

1. Entrainment of lobster larvae has been negligible at Pilgrim Station, while only low numbers of juveniles have been impinged on the intake screens.

2. The percentage of culls in the surveillance area in 1991 was again lower than the reference area, but the difference appears not to be power-plant related.

3. Analysis of commercial lobster pot-catch data indicate there is no relationship in the annual catch ratios between the surveillance and reference areas and the operational status of the Power Plant.

4. When testing for a relationship between the commercial legal lobster catch rate in the surveillance area and a measure of seasonal plant operation at Pilgrim Station (MDC Net %) for

the full and partial on-line power years (1973-83, 1985, 1990-1991), we found a nonsignificant Kendall's concordance. We have no control over positioning of the commercial gear spatially in the designated surveillance quadrats; lobster pots can be deployed far enough away from the discharge canal that the thermal current is probably not a major factor affecting lobster distribution.

5. Using a temporally limited dataset, there was no correlation between legal catch rates at any of the discharge stations and Plant MDC. However, there were significant negative correlations between sublegal catch rates and Plant MDC at Stations F, G, and H. As these stations (especially G) are most proximal to the discharge canal, we hypothesized that the speed of the discharge current at these sites impacted sublegal catches by reducing their mobility and this reducing their abundance at these sites.

Bluefish and Striped Bass

1. The stressors of impingement and entrainment at Pilgrim Station do not impact striped bass and bluefish because of their life histories - no local spawning and few juveniles move into western Cape Cod Bay.

2. However, the stressor of the thermal effluent from the Power Station does affect bass and bluefish via two paths - local

heating and induced current flow - which shift the spatial distributions of these two species in the Pilgrim area.

3. The discharge current at Pilgrim Station elicits an active behavioral response from bluefish and striped bass. There is an attraction of individual population members to the moving water as a feeding ground.

4. Concerning the heat, there is likely an attraction of both species to the thermal plume in the spring and late fall by temperatures close to those preferred.

5. Conversely, the waste heat also induces an avoidance response. In August and early September, bluefish and bass are repelled by high temperatures in the discharge creating an exclusion zone in the discharge canal and near-field outfall area.

6. Shifts in fish distribution induce further population effects. Attraction produces increased densities of both species in the discharge area which has a positive effect on the sportfishing at the Pilgrim Shorefront from an angler's point of view. However, this has a negative side, in that increased population densities increase vulnerability to exploitation, i.e., fishing mortality, and susceptibility to cold shock..

Atlantic Silverside

1. The Atlantic silverside is consistently the most abundant fish in the Pilgrim area.

2. Silverside eggs are rarely entrained at Pilgrim Station while their larvae have a very low incidence of entrainment.

3. The Atlantic silverside is the dominant species impinged at Pilgrim Station, with most silverside impingement occurring in the winter. There are large numbers of silverside seined in the intake each summer.

4. Based on thermal tolerance data, there is probably a 4.5×10^4 m^2 exclusion area to silversides off the discharge canal in mid-to-late summer.

5. The effects of the thermal plume are most likely minimal to the Atlantic silverside population because of their great abundance in the Pilgrim area and their ability to move out of the discharge area to avoid stressful temperatures.

Atlantic menhaden

1. The entrainment of menhaden eggs at Pilgrim Station is relatively low (with the exception of 1982), while larval entrainment is rare.

2. Impingement of menhaden was relatively light in 1991 at Pilgrim Station.

3. The catch rate by gill net of menhaden has been down since 1980. The catch rate in 1991 was the second lowest of our data record (1971-present).

4. Spring migrating menhaden, on occasion, have been attracted to the thermal discharge because the outfall temperatures are within their preferred range as compared to ambient values. Substantial documented mortalities of adult menhaden have occurred in the Pilgrim discharge canal in April of 1973 and 1975 caused by gas bubble disease. In the summer of 1978, a fish kill involving over 2,000 juvenile clupeids (including menhaden) occurred in the discharge area because of thermal stress perhaps aggravated by chlorine residuals.

5. Losses to the coast-wide menhaden population via entrainment, impingement, and gas bubble disease have been estimated to be negligible.

Winter Flounder

1. Due to their demersal nature, few winter flounder eggs have been entrained at Pilgrim Station. The entrainment of their larvae does not appear to pose much of a threat to overall stock abundance.

2. Winter flounder are commonly impinged at Pilgrim Station, however, so few are collected that impingement is not considered a major form of impact.

3. There is no apparent relationship between trawl catch data of winter flounder in the area of the discharge and plant operation. The marked decline in catch rate is believed due to depressed coast-wide stocks.

Tautog

1. Labrid eggs are a traditional dominant in entrainment collections, however due to difficulties in distinguishing cunner and tautog eggs and the abundance of the former, all labrid eggs are classified as cunner. Little is known of entrainment of tautog eggs, but it is not considered as serious impact. Similarly, the entrainment of their larvae does not appear to pose much of a threat to overall stock abundance.

2. Project dive records reveal that tautog are commonly sighted in the discharge canal at or near high tide. We believe they are attracted to the dense bed of blue mussels found growing on the boulders there.

3. There is no apparent relationship between gill-net catch data of tautog and plant operation.

4. Tautog are considered an important gamefish, however, catch by recreational anglers was low. Mortality caused by recreational fishing is negligible.

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on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (CHARACTERIZATION OF BENTHIC COMMUNITIES)
January-December 1991

to

BOSTON EDISON COMPANY
Regulatory Affairs Department
Licensing Division
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

From

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
89 Water Street
Woods Hole, MA 02543
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1 April 1992

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EXECUTIVE SUMMARY

This report represents results of quantitative data collected in March and October 1991 at established stations in the vicinity of the Pilgrim Nuclear Power Station (PNPS) and qualitative transect surveys conducted in the thermal effluent in March, June, October, and December of 1991. These investigations represent the most recent phase of the long-term efforts to monitor the effects of the thermal effluent on the benthic communities adjacent to the PNPS.

A variety of analytical techniques were used to assess community structure. Specific data on algal biomass, dominant fauna, species diversity, and faunal densities were analyzed along with overall community relationships.

QUANTITATIVE STUDIES

Faunal Studies

A total of 107 species of benthic invertebrates were found in the 1991 samples. The majority of species consisted of crustaceans (34), followed by mollusks and polychaetes (30 each). In comparison with the previous year, species richness increased at the Effluent station, with a record high observed in the fall. At the reference stations, no such trend in species richness was observed. The faunal community at the Effluent station was also characterized by a very high number of "unique" species (22) found in only one replicate.

Total densities recorded at the three stations were very high in March, due in large part to high counts of the blue mussel, *Mytilus edulis*. The Effluent station was highest in total density (about 500,000 individuals per m^2), whereas the Rocky Point station was lowest (about 160,000 individuals per m^2). In October the mussel counts dropped dramatically, causing a sharp decline of total densities at all three stations. Density at the Effluent station was highest (108,000 individuals per m^2); the lowest densities were recorded at the Rocky Point station (43,000 individuals per m^2).

In March, the 15 highest ranked species at each station accounted for 96 to over 99% of the total density at each station. The percentage of the 15 dominant species in September was lower, ranging from 87% to 93%. The lower percentage of the 15 most abundant species in the fall is the result of the decrease in the mussel populations. The absence of a true dominant in the benthic communities caused changes in the community structure, most noticeably at the Effluent station where the five most abundant species each contributed about 10% to the total fauna. In March, *Mytilus edulis* alone represented almost 75% of the fauna at that station. A total of 18 to 23 species comprised the 15 highest ranked species at all three stations in March and October. Most of these dominant species were amphipods (11 species in March, 12 species in October), followed by gastropods (4 species in March and October). *Mytilus edulis* was the only bivalve among the dominants during both seasons. Other phyla represented among the dominants were 1 tunicate (March and October), 1 isopod (March), and 2 echinoderms (March). Overall, the diversity of the dominant fauna in terms of represented phyla was much greater in the spring than in the fall.

Species diversity indices were obscured by the high density of *Mytilus edulis* in March, but almost identical with and without mussels in October. When the mussels are removed from the analysis, the spring diversity values are within the range expected in near coastal benthic communities. For example, Shannon's H' ranged from 2.04 (Effluent) to 3.88 (Rocky Point) in spring and from 3.40 (Rocky Point) to 4.22 (Effluent) in the fall. The abundance of the mussels in October was so low that their removal from the analysis caused the diversity index to decrease.

Community analysis by clustering or similarity techniques indicates that the Effluent station was very different from the reference stations in the spring and in the fall split into two replicate groups that each joined one of the reference stations. With NESS, the spring Effluent samples formed a cluster that was dissimilar from all other 1991 samples.

Similarity analysis by species for both March and September revealed that dominance patterns influenced the way the species groups joined. For example, most of the species that comprise the lists of highest ranked dominant species tend to cluster together, while the rare or infrequently encountered species comprise other groups.

Algal Studies

No additions to the cumulative algal lists were made as a result of the analysis of the March and October 1991 samples. The rock and cobble substrata found at the Effluent, Manomet Point, and Rocky Point stations were heavily populated with red algae, especially Irish moss (*Chondrus crispus*) and *Phyllophora* spp. Epiphytic algal species were observed at all stations, with *Chondrus* and *Phyllophora* serving as primary hosts.

Algal community overlap measures the similarity in algal species composition between stations. Community overlap between the three stations was high, indicating that they were very homogeneous with regard to shared species. In March 1991, the range in percent overlap of replicate samples was lower at the Effluent station (19.7%) than at either the Manomet Point (25.0%) or Rocky Point (21.7%) stations, evidence that individual samples at the Effluent station were more similar to one another than the samples from the reference stations. At all stations, range of percent overlap between replicates was less in October than in March, with the largest decrease occurring at the reference stations. Community overlap between the two reference stations was higher in October than it had been in March, whereas the overlap between either of the reference stations and the Effluent station declined from March to October. These results indicate that the replicates from each station were more homogeneous and that the Effluent station differed more from the reference stations in October than in March.

Total algal biomass was highest at Manomet Point in both March and October; the lowest total algal biomass values were found at the Effluent station in March and at Rocky Point in October. Biomass of *Chondrus crispus* was highest at Manomet Point in March and October; it was lowest at the Effluent station in March and at Rocky Point in October. *Phyllophora* spp. biomass was highest at Rocky Point in March and at the Effluent station in October; it was lowest at Manomet Point in March and at Rocky Point in October. The highest biomass of benthic algal species other than *Chondrus* and *Phyllophora* for both spring and fall was found at Rocky Point. The highest biomass of epiphytic algae was found at Manomet Point in March and at Rocky Point in October.

Analysis of variance (ANOVA) for total algal biomass showed a significant difference among the three stations in March that the Scheffé test attributed to the total algal biomass at the Effluent station being significantly different from the mean biomass at the control stations and from Manomet Point; by October, this difference had disappeared. Contributing to the variation in total algal biomass were differences in biomass values of epiphytic algae among the three stations significant enough, in both seasons, so that the Scheffé test could attribute them to the difference in epiphytic algal biomass at Manomet Point and Rocky Point. In addition, epiphytic algal biomass at the Effluent station, in March, was different from the mean biomass at the control stations and from the biomass at Manomet Point. In October, analysis of variance showed significant differences in *Chondrus* and *Phyllophora* biomass values among the three stations that were so slight that Scheffé's multiple comparison test could not distinguish the source of the variation.

QUALITATIVE TRANSECT SURVEYS

The qualitative transect studies performed to evaluate the *Chondrus crispus* community in the thermal plume area indicate that in 1991 the denuded and stunted areas remained in the condition typical of full or nearly full operation of the plant. The *Chondrus* denuded and stunted areas encompassed 1320.5 m^2 and 225 m^2, respectively, in the March 1991 survey. In June, following two months of non-operation of the plant, the denuded zone had decreased slightly to 1265 m^2 but the stunted zone had disappeared and was replaced by a region the divers described as a sparse zone, an area typified by normal looking *Chondrus* plants that are thinly distributed. The area of the denuded zone continued to decrease to 1080 m^2 in October and then increased slightly to 1200 m^2 in December. The stunted zone (283 m^2) reappeared in October and then decreased in area by December to 183 m^2.

1.0 INTRODUCTION

This report represents a continuation of the long-term (18 yr) algal and faunal studies at Pilgrim Nuclear Power Station (PNPS) that are intended to monitor the effects of the thermal effluent. The program has essentially remained unchanged for the last ten years. Quantitative benthic algal and faunal sampling is conducted during the spring and fall at two reference sites, Rocky Point and Manomet Point, and at a site offshore of the effluent canal (Figure 1). Qualitative SCUBA surveys of algal cover in the effluent thermal plume are conducted quarterly during March, June, September, and December. This Semi-Annual Report includes quantitative data from samples that were collected in March and October 1991 and qualitative observations recorded in March, June, October, and December 1991. Work was performed under BECo Purchase Order 68003, in accordance with requirements of the PNPS NPDES Permit No. MA 0003557.

2.0 METHODS

2.1 FIELD SAMPLING

The sampling sites are the same locations that have been sampled since the beginning of the monitoring program, approximately 10 years ago. The stations are located by the following established procedures. Line-of-sight positions are established using highly visible structures located on the shore as reference points. The Rocky Point station is located by lining up the microwave relay tower with the PNPS red and white off-gas stack. The Effluent station, located approximately 120 m offshore, is identified along the center line between the two discharge jetties. The Manomet Point station is located by lining up the two southernmost telephone poles on top of Manomet Point. Line-of-sight positioning, combined with lead-line depth checks (10 ft. MLW) ensures station relocation to within a radius of 20 to 30 m of the original station position. The field team deploys a temporary buoy to mark the station locations.

All sampling is done by SCUBA-equipped biologists operating from a small boat. For the quantitative algal and faunal studies, five replicate samples delineated by a metal quadrant that measures 0.33 m on a side (0.1089 m^2) are taken from the surface of rocks at each station.

Upon entering the water, the divers descend to the bottom and locate suitable rocks for placement of the quadrant. Divers assess algal and faunal cover and select rocks that are considered typical for the station. All quadrate samples are taken within 10 m of the designated station location.

All attached flora and fauna within the quadrant are scraped from the rock and drawn through an airlift device into a 0.5-mm mesh bag (Figure 2). Field labels with station, collection date, and

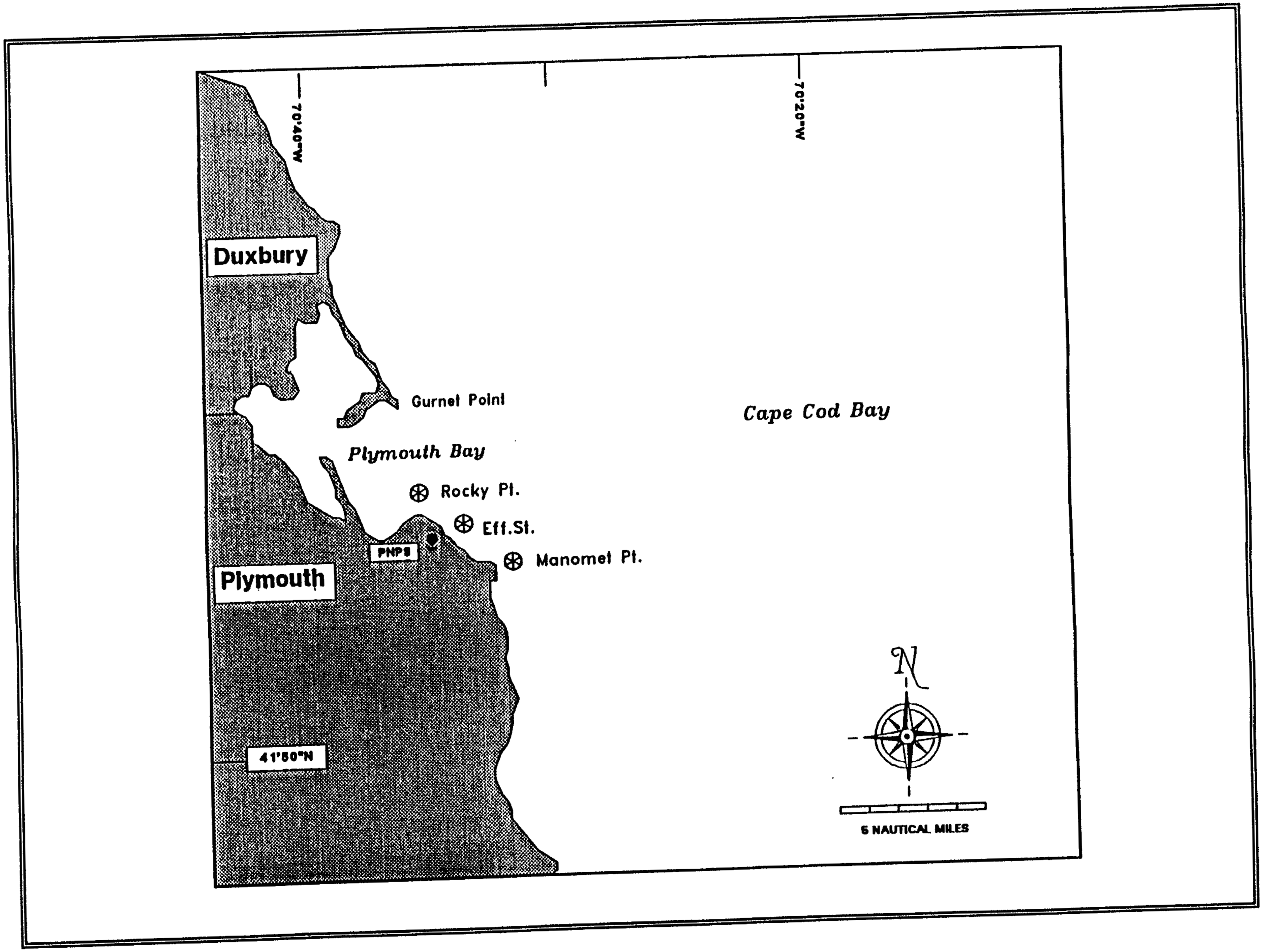

Figure 1. Location of Benthic Sampling Sites near Pilgrim Station.

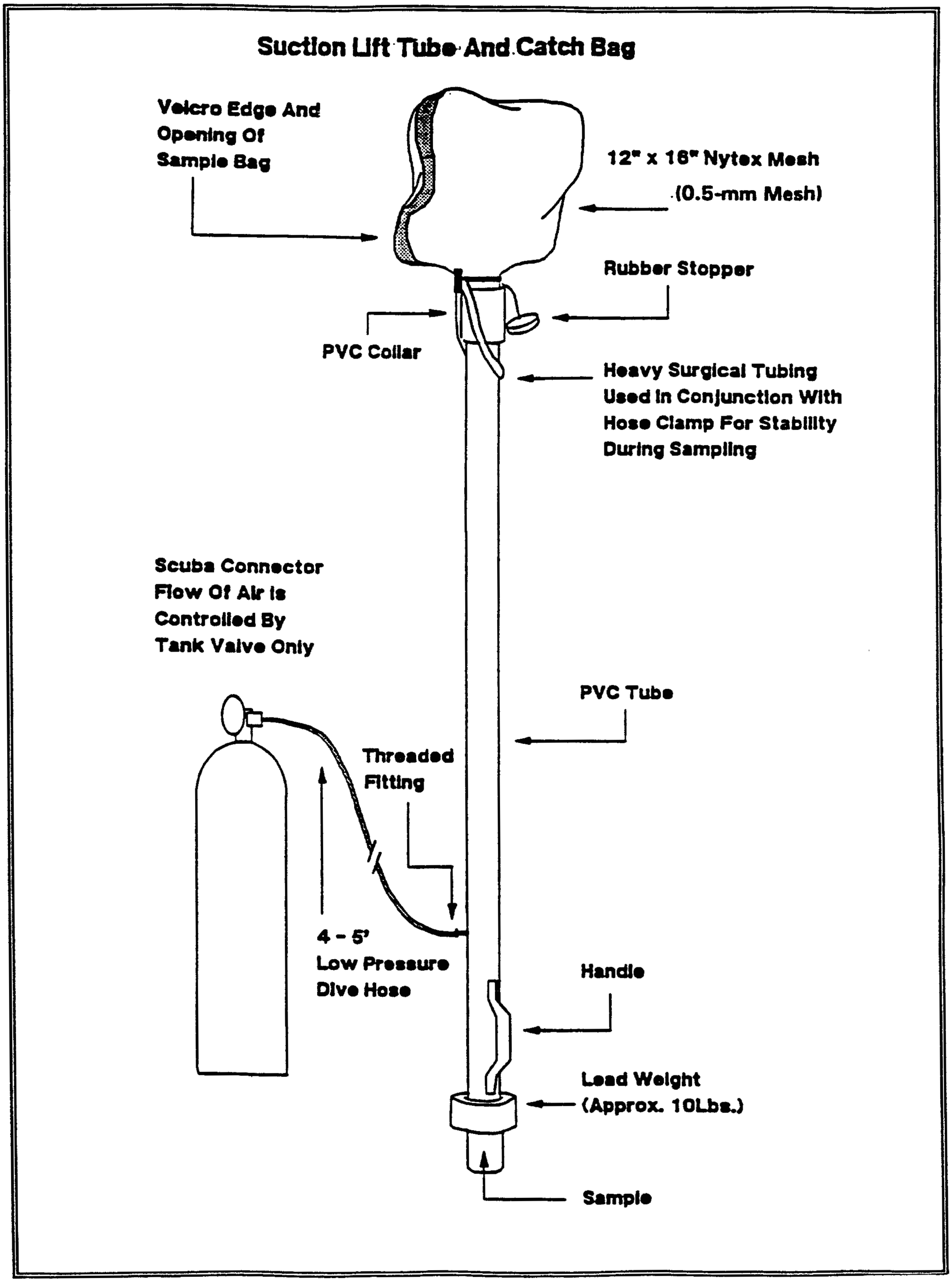

Figure 2. Suction Lift Device Used by Divers to Collect Benthic Samples.

replicate number are placed in sample bags before sample collection. After sample collection, the sample bag is closed with a rubber stopper and placed in a large catch bag,and a new bag is attached to the airlift. The divers then locate the next suitable rock and repeat the sampling process. After the five replicates are collected at a station they are delivered to a biologist on the boat for processing.

While the vessel is underway to the next station, the contents of each bag are transferred to a 1-gal plastic jar, labeled, and preserved with 10% buffered formalin. Approximately 100 g of Borax is added to each jar as a buffering agent to prevent softening of calcified shells.

For the qualitative transect survey, SCUBA observations are made along the axis of the discharge canal. A line is extended across the mouth of the discharge canal (Figure 3). A weighted central transect line (CTL), marked at 10-m intervals, is then attached to the center of this line and deployed along the central axis of the canal to a distance of 100 m offshore. Using a compass, divers extend a 30-m measuring line, marked at 1-m intervals, perpendicular to the CTL. A diver swims along this third line, recording changes in algal cover from the CTL through the denuded and stunted *Chondrus* areas to where the algal cover becomes normal.

According to procedures established by Taxon (1982) and followed in subsequent years, the distinction between "denuded" and "stunted" zones is based on the growth morphology of *Chondrus crispus*. The denuded zone is defined as that area where *Chondrus* occurs only as stunted plants restricted to the sides and crevices of rocks. In this area, *Chondrus* is found on the upper surfaces of rocks only where the microtopography of the rock surfaces creates small protected areas. In the stunted zone, *Chondrus* is found on the upper surfaces of the rocks but is noticeably inferior in height, density, and frond development compared to unaffected areas. In 1991 the divers included a distinction between a stunted zone and a sparse zone. The sparse zone is an area with normal looking *Chondrus* plants which are very thinly distributed. The normal zone is considered to begin at the point where *Chondrus* height and density are fully developed. The dive team must keep in mind while taking measurements that the shallow depths northwest of the discharge canal preclude normal *Chondrus* growth. In addition to observing algal cover, the divers record any unusual occurrences or events in the area and note the location of any distinctive algal or faunal associations.

2.2 LABORATORY ANALYSIS

In the laboratory, the algal and faunal fractions of the samples are separated by washing the animals off the algae onto a 0.5-mm-mesh screen. The animals are preserved in a solution of 70% ethanol. The algal fraction is preserved in a 10% formalin solution. The faunal samples are labeled

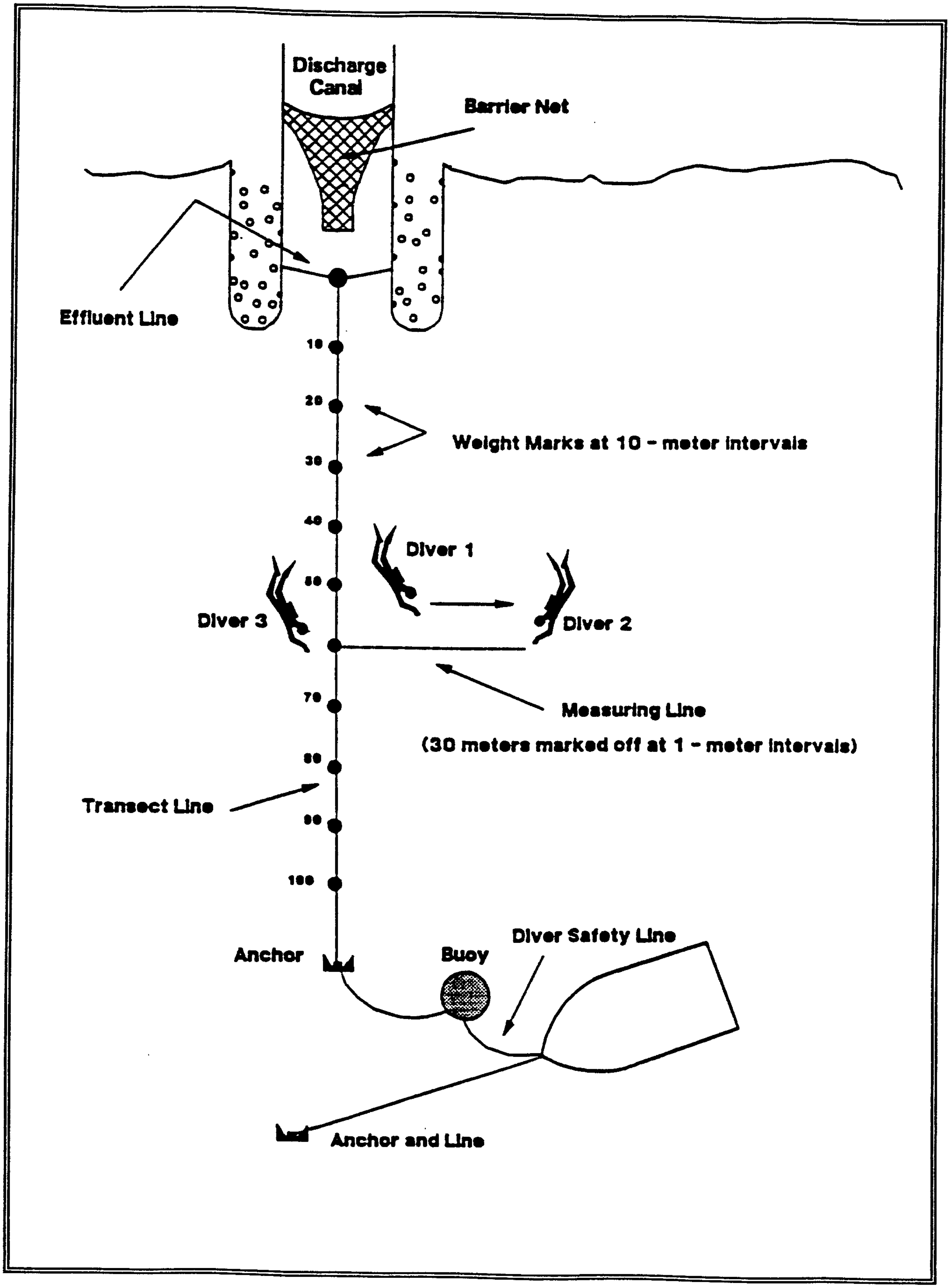

Figure 3. Design of the Qualitative Benthic Transect Sampling Program at Pilgrim Station.

and stored in 16-oz glass or plastic jars until sorting. Algal samples are labeled and stored in 1-gal plastic jars until sorting.

Each replicate sample is processed separately. The algal component of each sample is examined, using both dissection and compound microscopes, to identify all species of macroalgae and, in addition, record the presence or absence of 38 indicator species. Important algal references used to identify and confirm names are Taylor (1957), Parke and Dixon (1976), and South (1976). Thirty-seven of the indicator species were originally chosen by Taxon in September 1978, having been carefully selected from a list of the several hundred algal species recorded from the PNPS study sites between 1974 and 1978 (Taxon, 1982). One species (*Cladophora* spp.) was added in 1988 (BECo, 1988). The indicator species include members of each of the major algal families from a variety of habitats, including all of the dominant species within the study area, the majority of the macrophytic species, and the most common epiphytic species (Table 1). Therefore, the indicator species comprise the most substantial part of the algal community as measured by both percent cover and biomass, although they constitute only a small fraction of the flora inhabiting the study area in terms of the number of species.

Dry-weight biomass of all macroalgae in each sample is reported as total biomass and for four separate algal fractions: *Chondrus crispus, Phyllophora* spp., epiphytic species, and the remaining benthic species. Each fraction is weighed on a Mettler balance after being dried for 72 h in an oven set at 80°C.

A 25% aliquot of the faunal fraction of each sample is processed and the remaining 75% of the sample is archived. Prior to sorting, the 25% aliquot is stained with a saturated alcoholic solution of Rose Bengal for at least 4 h, but no longer than 48 h to avoid overstaining. The samples are examined under a dissecting microscope and each organism or fragment thereof removed. Invertebrates are sorted to major taxonomic groups, such as polychaetes, crustaceans, bivalves, gastropods, echinoderms, and other miscellaneous phyla. The blue mussel *Mytilus edulis* is left with the residue and counted during the sorting process.

Final identification is to the lowest possible taxon (usually to species). During identification, the counts of each species are recorded. A new reference collection for the PNPS program has been developed from the 1990 samples and will serve as a voucher collection for subsequent identifications. The samples are archived for a minimum of three years after collection.

Table 1. Algal Indicator Species used for Quantitative Community Analysis.

Chlorophyta (Green Algae)	Rhodophyta (Red Algae)
Bryopsis plumosa	*Ahnfeltia plicata**
*Chaetomorpha linum**	*Antithamnion americanum**
*C. melagonium**	*Bonnemaisonia hamifera**
Cladophora spp.*#	*Callophyllis cristata*
*Enteromorpha flexuosa**	*Ceramium rubrum**
*Rhizoclonium riparium**	*Chondrus crispus**
*Ulva lactuca**	*Corallina officinalis**
	*Cystoclonium purpureum**
Phaeophyta (Brown Algae)	*Gracilaria tikvahiae*
	Gymnogongrus crenulatus
Chordaria flagelliformis	*Membranoptera alata**
*Desmarestia aculeata**	*Palmaria palmata*
D. viridis#	*Phycodrys rubens**
Laminaria digitata	*Phyllophora truncata**
L. saccharina	*P. pseudoceranoides**
Sphacelaria cirrosa#	*P. traillii*
	Plumaria elegans
	*Polyides rotundus**
	Polysiphonia elongata
	*P. fibrillosa**
	*P. harveyi**
	*P. nigrescens**
	*P. urceolata**
	*Rhodomela confervoides**
	*Spermothamnion repens**

* Species found in 1991 samples.
# Species present in March 1991 but absent in October 1991.

2.3 DATA ANALYSIS

All faunal data are kept on specially designed project data sheets to facilitate computer entry. Data are entered into a spreadsheet format on a personal computer. The software used is Quattro Pro®. Some basic data summaries and calculations can be made while the data are in this form. Following data entry and reorganization in the spreadsheet, a hard copy of the raw data is generated and verified against the original coding sheets. All entry errors are corrected at this point. Data files are then transferred to the Woods Hole Oceanographic Institution (WHOI) VAX computer for analysis. Analytical software consists of a suite of programs developed specifically for the analysis of benthic data. In addition to a variety of data-management and modification utilities, these programs include PRARE1 and COMPAH. PRARE1 summarizes the data for each sample, calculates a variety of diversity-related indices, and generates a rarefaction curve. COMPAH is a multivariate classification package that allows a wide variety of user-specified options for similarity indices and clustering strategies, including both normal (i.e., by station) and inverse (i.e., by species) analyses.

The individual species composing the fauna at each station are rank ordered by abundance. The most abundant species is listed first, followed in order by less abundant forms. The percent contribution of each species to the total fauna is denoted by a decreasing total percentage starting with the most abundant species and ending with the most rare. Basic statistical treatments include calculation of means of abundances per station and extrapolation to density per m^2.

Species richness is interpreted by using a jackknife procedure in combination with pooled species data to evaluate the contribution of rare species in the communities (Heltshe and Forrester, 1983). This procedure takes into account that random samples are not necessarily representative of a population. The jackknife estimate of species richness is a function of the number of so-called "unique" species present at a station, that is those that are present in one and only one replicate out of five. The jackknife estimate of species richness ($\hat{S}$) is expressed as:

$$\hat{S} = S + \left[\frac{(n-1)}{n}\right] k$$

where S represents the pooled species numbers at each station, n is the number of replicates, and k is the number of unique species. The variance of estimated species richness [**var** ($\hat{S}$)] is also calculated to measure the spatial distribution of unique species.

Measures of diversity calculated for each sample and station include the Shannon-Wiener information (H') and evenness (J') indices and rarefaction curves constructed according to the method of Hurlbert (1971). Shannon's H' has been shown to be a biased estimator and for small samples will underestimate true population information (Smith and Grassle, 1977). Hurlbert's expected species index of diversity is an unbiased estimator and is thus particularly useful when small and unequal sample sizes must be compared.

The measure of similarity developed by Grassle and Smith (1976), the Normalized Expected Species Shared (NESS), combined with group average sorting is used for cluster analysis. NESS is based on the expected number of species shared between random samples of size m drawn from a population, and is sensitive to the less common species in the populations to be compared. For the present analyses, m was set at 200.

The Bray-Curtis similarity measure, combined with group average sorting, is also used (Boesch, 1977). These values are calculated for stations (normal) and species (inverse). For the latter, data are analyzed using numbers of individuals.

In order to evaluate patterns in the station and species similarities, a nodal analysis is performed using the results of the similarity analyses described above. This procedure is especially useful when evaluating the combined spring and fall data. Nodal analysis is a method of relating normal and inverse classifications to aid in the interpretation of cluster analyses. The method uses two-way tables that show replicate groups on the vertical side and species groups on the horizontal side. This technique is used to measure constancy and fidelity. Constancy is a proportion derived from the number of occurrences of a species group in a replicate group as compared with the total possible occurrences. Fidelity is the degree of restriction of a species group to a replicate group.

For the algae, community overlap was calculated using Jaccard's coefficient of community (Grieg-Smith, 1964) to measure the similarity in algal species composition among the Effluent, Manomet Point, and Rocky Point stations. Jaccard's coefficient provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence and does not consider differences in their abundance.

Comparison of means in a single classification Model I ANOVA (Sokal and Rohlf, 1969), for each season separately, were performed to determine whether there were any differences among stations in algal biomass. Sources of variation were among stations (df=2) and within stations (df=12); $F_{.05[2,12]} = 3.89$. When the ANOVA determined a significant difference in algal biomass among stations then Scheffé's multiple comparison test (Sokal and Rohlf, 1981, p.256) was performed to determine where the difference occurred. Scheffé's test allows comparison between a pair of stations, for example, the two reference stations, or between one station and the mean of the other two, for example, the Effluent station versus the mean of Rocky Point and Manomet Point.

3.0 RESULTS

3.1 QUANTITATIVE FAUNAL MONITORING

3.1.1 Systematics

Since the sampling effort in April 1990, a total of 138 species have been identified, 107 of which were found in samples taken in March and October 1991. The largest taxonomic group were the crustaceans, contributing 34 species (32%), followed by polychaetes and mollusks contributing 30 species (28%) each. The other groups, such as nemerteans, echinoderms, and anemones, were represented by few species that together accounted for the remaining 12% of the fauna. A species list can be found in Appendix A. In comparison to 1990, the number of species was slightly lower in 1991, mostly due to a reduced number of polychaetes and mollusks.

Some 10 species were added to last year's species list. This slight increase in the total number of species found since the spring of 1990 agrees well with the expectations outlined in the previous annual report (BECo, 1991b).

3.1.2 Species Richness

Species richness values for all three stations in spring and fall 1991 are listed in Table 2. Data are presented as total species per replicate for each station, with a mean value over all replicates at each station and a cumulative total representing pooled species numbers at each station.

In the spring of 1991, the highest number of species was found at Rocky Point (total: 78, average per replicate: 48.6). Manomet Point had the lowest number of species (total: 62, average per replicate: 38.8). The Effluent station was intermediate with 72 species total (average per replicate: 43.2). The fall samples were characterized by an increase in the number of species that was most distinct at the Effluent station with a total of 93 species (average per replicate: 59.4). Rocky Point was intermediate with 74 species (average per replicate: 46.8), and Manomet Point was lowest with 70 species (average per replicate: 47.8). The number of species at the Effluent station is the highest ever reported for this station.

Table 2. **Faunal Species Richness at the Effluent, Manomet Point, and Rocky Point Stations in March and October 1991.**

	Effluent		Manomet Point		Rocky Point	
	Spring	Fall	Spring	Fall	Spring	Fall
No. Species/Replicate	47, 35, 44, 53, 37	65, 60, 60, 61, 51	42, 42, 39, 35, 36	46, 44, 48, 53, 48	50, 51, 51, 43, 48	39, 46, 49, 58, 42
Mean ± Standard Deviation	43.2 ± 7.36	59.4 ± 5.13	38.8 ± 3.27	47.8 ± 3.35	48.6 ± 3.36	46.8 ± 7.33
No. Species/Station	72	93	62	70	78	74
Jackknifed Estimate Species Richness ($\hat{S}$)	95.8	120.5	77.0	86.3	101.8	95.3
Variance ($\hat{S}$)	42.24	30.36	0.96	2.56	11.84	8.96

In order to assess the rare species that might be present at the stations but were not found because of the relatively small area sampled, the jackknife estimate of Heltshe and Forrester (1983) was calculated (see Section 2.3), resulting in an estimated species richness value ($\hat{S}$). In March 1991, the estimated species richness was highest at Rocky Point, lowest at Manomet Point, and intermediate at the Effluent station; i.e., the estimated species richness showed similar patterns to the actual number of species found in the samples. In October 1991, estimated species richness was highest at the Effluent station, lowest at Manomet Point, and intermediate at Rocky Point. Again, the estimated and actual species richness values showed similar patterns.

Between March and October 1991, species richness increased at the Effluent station and Manomet Point, but declined slightly at Rocky Point. The increase in species richness at the Effluent station appears to be a continuation of a trend observed in 1990, whereas no seasonal or long-term pattern could be detected at the reference stations.

3.1.3 Faunal Density

Faunal densities for each station, expressed as mean number of individuals per replicate (extrapolated from the 25% aliquot that was analyzed) and number of individuals per m^2, are listed in Table 3. Densities of the mussel *Mytilus edulis* are listed separately, along with the densities of the remaining fauna, to demonstrate the often strong influence of the mussels on faunal densities. Overall, densities dropped considerably between spring and fall 1991 at all three stations due to a sharp decline in the *Mytilus edulis* populations (Figure 4). The most drastic decline in mussel density was found at the Effluent station (almost 400,000 individuals per m² in March, about 5000 individuals per m² in October). At the reference stations, mussels declined from 120,000 to about 3500 individuals per m² at Manomet Point and from almost 100,000 to about 1500 individuals per m² at Rocky Point. The changes in densities for the remaining fauna were, in comparison, minor. Densities of two additional species are shown in Figure 4. *Jassa falcata*, which has historically been the most abundant amphipod at all stations, exhibited a sharp decline in density in October 1991 at the Effluent and Rocky Point stations but increased at Manomet Point. Overall, *Jassa falcata* has declined steadily at the Effluent and Rocky Point stations since September 1990 and appears to have been replaced by other amphipods (see Species Dominance, Section 3.1.4 below). In contrast, the gastropod *Lacuna vincta*, increased markedly in abundance in the October 1991 samples at all three stations when compared with the very low spring densities.

Table 3. Faunal Densities at the Effluent, Manomet Point, and Rocky Point Stations in March and October 1991.

Station	Season	Density					
		Total Fauna		*Mytilus edulis*		Remaining Fauna	
		Mean ($\bar{X}$) No. Indiv./ Rep.	No. Indiv./m²	Mean ($\bar{X}$) No. Indiv./ Rep.	No. Indiv./m²	Mean ($\bar{X}$) No. Indiv./ Rep.	No. Indiv./m²
EFF	Spring	59,341	517,631	41,945	385,368	14,396	132,263
	Fall	11,747	107,871	570	5,238	11,177	102,533
MP	Spring	20,534	188,660	13,914	127,839	6,620	60,821
	Fall	9,966	91,511	375	3,445	9,591	88,056
RP	Spring	17,285	158,804	10,513	96,586	6,772	62,218
	Fall	4,714	43,284	158	1,455	4,556	41,829

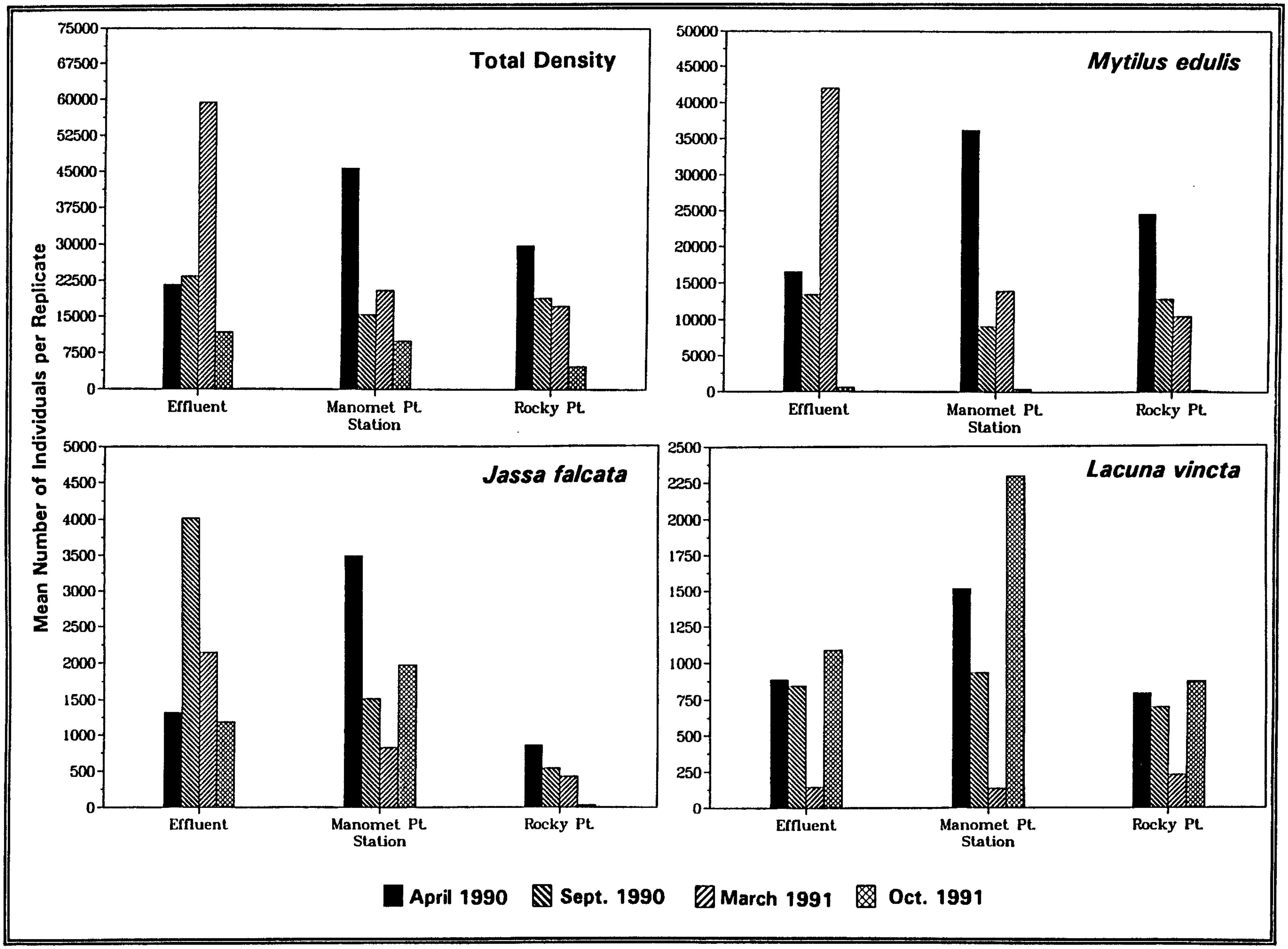

Figure 4. Density of Benthic Fauna in April and September of 1990 and March and October of 1991.

3.1.4 Species Dominance

The fifteen numerically dominant species of each station in spring and fall 1991 are listed in Tables 4 through 6. A suite of 23 and 18 species comprised the dominants found in the March and October samples, respectively. The October dominants included 12 amphipods, 4 gastropods, 1 bivalve (*Mytilus*), and 1 tunicate. Eleven of these species were among the dominants of all three stations, 5 were among the dominants of two stations, and 2 species were among the dominants of only one station (1 at the Effluent station, 1 at Rocky Point). These data indicate that the faunal composition was very similar at all three stations, although the ranks of the dominants shared by three stations were very different at each station.

In the spring, the top ranking species at all three stations were much more similar than in the fall. All stations were dominated by *Mytilus edulis* and *Jassa falcata*, one or two species of *Corophium*, and *Lacuna vincta*. A similar tendency could be observed in 1990, when the suite of dominants was quite similar at all stations in the spring, but differed in the fall (aside from *Mytilus* which remained the top ranking species in the fall of 1990).

The sharp decline of *Mytilus* in the fall of 1991 resulted in a very different community structure in that a true dominant was not present at any station. Instead, the stations were characterized by four or five species occurring at high abundances. At the Effluent station, four amphipods and the snail *Lacuna vincta* each contributed roughly 10% of the total fauna, whereas *Mytilus* represented only about 5%. Only 7 of the spring dominants at this station were also among the fall dominants. The diversity of the dominant fauna in terms of represented phyla reported in the spring was no longer seen in the fall when almost all dominants were amphipods (12 out of 15 species). At the reference stations, the community structure resembled more the communities normally seen in this project, i.e., one species clearly dominating and all others contributing only minor percentages of the total fauna. At Manomet Point, the two most abundant species were *Lacuna vincta* and *Jassa falcata* with each contributing about 20% to the total fauna. The lower ranking species represented between 1 and 10% of the total fauna. The most abundant species at Rocky Point was the amphipod *Dexamine thea* (34% of the total fauna); the second and third ranking species *Lacuna vincta* and *Caprella penantis* contributed roughly 20 and 10%, respectively, of the total fauna. The differences in the composition of the dominant fauna at both reference stations between spring and fall was much less than at the Effluent station: 13 of the spring dominants at Manomet Point and 12 at Rocky Point were also among the fall dominants of those stations.

Table 4. Fifteen Most Abundant Species at the Effluent Station in March and October 1991.

EFFLUENT					
Spring 1991			Fall 1991		
Species	Mean Number per Replicate	Percent of Identified Fauna	Species	Mean Number per Replicate	Percent of Identifie d Fauna
Mytilus edulis (Bivalve)	10,486.0	74.45	*Caprella penantis* (Amphipod)	375.0	13.12
Jassa falcata (Amphipod)	2,137.4	15.18	*Dexamine thea* (Amphipod)	331.8	11.71
Corophium insidiosum (Amphipod)	613.4	4.36	*Calliopius laevisculus* (Amphipod)	320.8	11.22
Corophium acutum (Amphipod)	447.8	3.18	*Jassa falcata* (Amphipod)	294.6	10.31
Lacuna vincta (Gastropod)	142.6	1.01	*Lacuna vincta* (Gastropod)	271.4	9.49
Caprella penantis (Amphipod)	60.8	0.43	*Mytilus edulis* (Bivalve)	142.6	4.99
Calliopius laevisculus (Amphipod)	18.0	0.13	*Corophium tuberculatum* (Amphipod)	129.8	4.54
Dexamine thea (Amphipod)	17.2	0.12	*Pontogeneia inermis* (Amphipod)	107.0	3.74
Cerebratulus lacteus (Nemertean)	14.2	0.10	*Corophium acutum* (Amphipod)	105.4	3.69
Idotea phosphorea (Isopod)	13.2	0.09	*Corophium bonelli* (Amphipod)	93.4	3.27
Asterias forbesi (Echinoderm)	11.4	0.08	*Caprella linearis* (Amphipod)	76.4	2.67
Pholoe minuta (Polychaete)	10.0	0.07	*Mitrella lunata* (Gastropod)	70.4	2.46
Eulalia viridis (Polychaete)	9.4	0.07	*Ischyrocerus anguipes* (Amphipod)	66.2	2.32
Molgula sp. (Tunicate)	7.2	0.05	*Amphithoe rubricata* (Amphipod)	53.0	1.85
Strongylocentrotus droebachiensis (Echinoderm)	6.8	0.05	*Pleusymtes glaber* (Amphipod)	50.4	1.76
TOTAL OF 15 SPECIES	13,995.4	99.37	TOTAL OF 15 SPECIES	2488.2	87.14
REMAINING IDENTIFIED FAUNA - 57 SPECIES	89.8	0.63	REMAINING IDENTIFIED FAUNA - 75 SPECIES	370.2	12.86
TOTAL IDENTIFIED FAUNA - 72 SPECIES	14,085.2	100.00	TOTAL IDENTIFIED FAUNA - 90 SPECIES	2858.4	100.00

Table 5. Fifteen Most Abundant Species at the Manomet Point Station in March and October 1991.

MANOMET POINT					
Spring 1991			Fall 1991		
Species	Mean Number per Replicate	Percent of Identified Fauna	Species	Mean Number per Replicate	Percent of Identified Fauna
Mytilus edulis (Bivalve)	3,478.6	67.76	*Lacuna vincta* (Gastropod)	572.2	23.34
Jassa falcata (Amphipod)	827.0	16.11	*Jassa falcata* (Amphipod)	490.6	20.01
Corophium acutum (Amphipod)	200.6	3.91	*Caprella penantis* (Caprellid)	232.8	9.50
Lacuna vincta (Gastropod)	133.0	2.59	*Dexamine thea* (Amphipod)	196.2	8.00
Corophium bonelli (Amphipod)	127.8	2.49	*Margarites umbilicalis* (Gastropod)	164.6	6.71
Margarites umbilicalis (Gastropod)	76.4	1.49	*Corophium acutum* (Amphipod)	161.0	6.57
Molgula sp. (Tunicate)	46.4	0.90	*Mytilus edulis* (Bivalve)	93.8	3.83
Idotea phosphorea (Amphipod)	35.0	0.68	*Corophium bonelli* (Amphipod)	93.4	3.81
Calliopius laevisculus (Amphipod)	23.4	0.46	*Pleusymtes glaber* (Amphipod)	83.2	3.39
Dexamine thea (Amphipod)	18.8	0.37	*Calliopius laevisculus* (Amphipod)	59.0	2.41
Caprella penantis (Amphipod)	18.8	0.37	*Ischyrocerus anguipes* (Amphipod)	36.2	1.48
Ischyrocerus anguipes (Amphipod)	18.0	0.35	*Caprella linearis* (Amphipod)	32.8	1.34
Amphitoe rubricata (Amphipod)	16.2	0.32	*Molgula* sp. (Tunicate)	30.8	1.26
Pleusymtes glaber (Amphipod)	15.2	0.30	*Mitrella lunata* (Gastropod)	26.2	1.07
Pontogeneia inermis (Amphipod)	14.6	0.28	*Pontogeneia inermis* (Amphipod)	25.2	1.03
TOTAL OF 15 SPECIES	5,049.8	98.38	TOTAL OF 15 SPECIES	2,298.0	93.75
REMAINING IDENTIFIED FAUNA - 47 SPECIES	83.8	1.62	REMAINING IDENTIFIED FAUNA - 54 SPECIES	153.6	6.25
TOTAL IDENTIFIED FAUNA - 62 SPECIES	5,133.6	100.00	TOTAL IDENTIFIED FAUNA - 69 SPECIES	2451.6	100.00

Table 6. Fifteen Most Abundant Species at the Rocky Point Station in March and October 1991.

ROCKY POINT					
Spring 1991			Fall 1991		
Species	Mean Number per Replicate	Percent of Identified Fauna	Species	Mean Number per Replicate	Percent of Identified Fauna
Mytilus edulis (Bivalve)	2,628.2	60.82	*Dexamine thea* (Amphipod)	394.4	34.30
Jassa falcata (Amphipod)	431.8	10.00	*Lacuna vincta* (Gastropod)	217.8	18.94
Corophium acutum (Amphipod)	260.4	6.03	*Caprella penantis* (Amphipod)	126.2	10.97
Lacuna vincta (Gastropod)	225.6	5.22	*Corophium bonelli* (Amphipod)	76.0	6.61
Molgula sp. (Tunicate)	75.8	1.75	*Mytilus edulis* (Bivalve)	39.5	3.44
Margarites umbilicalis (Gastropod)	75.4	1.75	*Margarites umbilicalis* (Gastropod)	30.4	2.64
Corophium bonelli (Amphipod)	73.4	1.70	*Corophium acutum* (Amphipod)	24.2	2.10
Mitrella lunata (Gastropod)	69.2	1.60	*Onoba aculea* (Gastropod)	23.0	2.00
Onoba aculea (Gastropod)	55.2	1.28	*Calliopius laevisculus* (Amphipod)	21.6	1.88
Pontogeneia inermis (Amphipod)	54.6	1.26	*Amphithoe rubricata* (Amphipod)	19.4	1.69
Ischyrocerus anguipes (Amphipod)	53.0	1.23	*Pontogeneia inermis* (Amphipod)	17.4	1.51
Strongylocentrotus droebachinesis (Echinoderm)	49.4	1.14	*Mitrella lunata* (Gastropod)	17.0	1.48
Dexamine thea (Amphipod)	39.6	0.92	*Molgula* sp. (Tunicate)	15.6	1.36
Caprella penantis (Amphipod)	29.2	0.68	*Pleusymtes glaber* (Amphipod)	10.8	0.94
Idotea phosphorea (Isopod)	23.8	0.55	*Ischyrocerus anguipes* (Amphipod)	10.0	0.87
TOTAL OF 15 SPECIES	4,144.6	95.93	TOTAL OF 15 SPECIES	1,043.3	90.73
REMAINING IDENTIFIED FAUNA - 63 SPECIES	176.6	4.07	REMAINING IDENTIFIED FAUNA - 60 SPECIES	106.7	9.27
TOTAL IDENTIFIED FAUNA - 78 SPECIES	4,321.2	100.00	TOTAL IDENTIFIED FAUNA - 75 SPECIES	1150.0	100.00

3.1.5 Species Diversity

Diversity-related community parameters for March and October 1991 are presented in Tables 7 and 8, respectively. In the spring, the lowest diversity was observed at the Effluent station with a Shannon-Wiener index of 1.34 (mussels included). The highest Shannon-Wiener index was calculated for Rocky Point at 2.49. When mussels were excluded from the analysis, all H' values increased by a factor of approximately 1.5. Hurlbert's rarefaction method revealed similar results; the number of expected species per 5000 individuals increased roughly 1.5-fold when mussels were excluded.

The analysis of the October 1991 samples produced very different results. Due to the very low mussel counts at all stations (see above), the Shannon-Wiener indices with and without mussels were almost identical for each station, differing by 0.1 or less. A very striking difference to previous years, also caused by the low mussel abundances, is the slight decrease of H' when mussels are excluded. The highest diversity was found at the Effluent station ($H'=4.30$), and the lowest diversity was found at Rocky Point ($H'=3.50$). Diversity at Manomet Point was intermediate ($H'= 3.68$) and most similar to Rocky Point. These values are considerably higher than the corresponding spring values, but are within range of the diversities found in the fall samples from the previous year (mussels excluded). With Hurlbert's rarefaction method, the ranking of the two reference stations is reversed with Rocky Point showing more expected species per 5000 individuals (72.1) than Manomet Point (59.9). Diversity measured with rarefaction at the Effluent station is still the highest at 73.6 expected species per 5000 individuals, and it is very similar to Rocky Point. Diversities measured in October 1991 are expressed as curves in Figure 5. Only stations with *Mytilus* included are shown in this figure because of the negligible difference caused by the absence of mussels from the analysis.

Table 7. Community Parameters for the Effluent, Manomet Point, and Rocky Point Stations in March 1991.

Station	Density (Ind./m²)	Total No. Species	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2500 Indiv.	Species per 5000 Indiv.	Shannon-Wiener (*H'*)	Evenness (*J'*)
Effluent	517,631	72	6.3	12.0	16.7	25.9	34.5	1.34	0.217
Without *Mytilus*	132,271	71	9.7	22.2	30.4	42.4	51.9	2.04	0.332
Manomet Point	188,660	62	10.3	20.0	25.2	33.3	41.6	1.82	2.306
Without *Mytilus*	60,821	61	15.7	27.8	34.7	46.6	55.7	2.85	0.480
Rocky Point	158,804	78	15.3	28.5	35.8	47.7	57.9	2.49	0.395
Without *Mytilus*	62,218	77	21.6	37.7	47.0	60.4	69.9	3.88	0.619

Table 8. Community Parameters for the Effluent, Manomet Point, and Rocky Point Stations in October 1991.

Station	Density (Ind./m²)	Total No. Species	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2500 Indiv.	Species per 5000 Indiv.	Shannon-Wiener (*H'*)	Evenness (*J'*)
Effluent	107,871	93	23.9	40.6	49.3	62.0	73.6	4.30	0.658
Without *Mytilus*	102,533	92	23.4	40.2	48.9	61.8	73.5	4.22	0.648
Manomet Point	91,511	70	18.8	32.7	40.5	51.6	59.9	3.68	0.600
Without *Mytilus*	88,056	69	18.1	32.1	40.0	51.1	59.3	3.58	0.587
Rocky Point	43,284	74	20.6	38.3	47.4	61.3	72.1	3.50	0.564
Without *Mytilus*	41,829	73	20.0	37.8	46.8	60.8	71.6	3.40	0.550

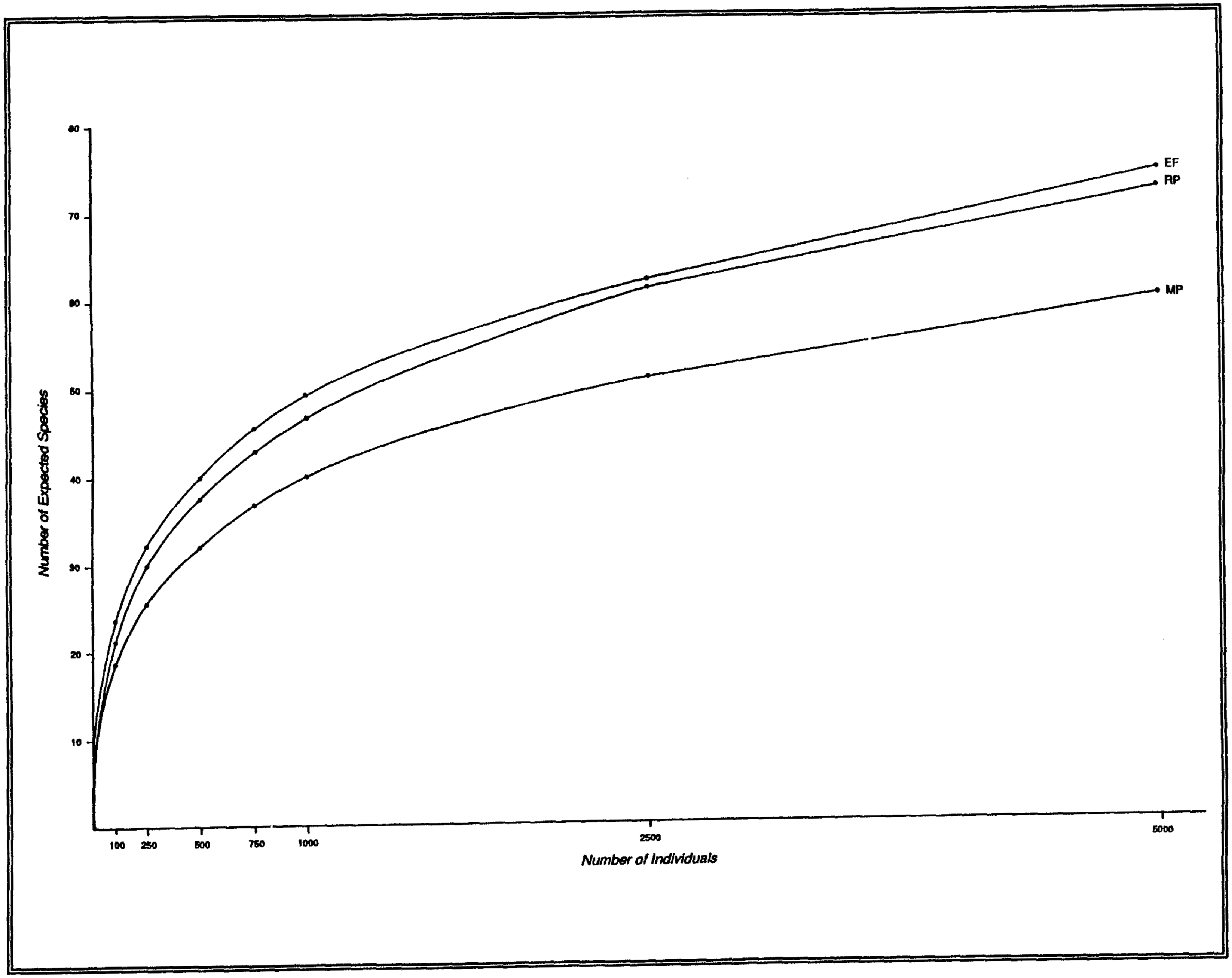

Figure 5. Hurlbert Rarefaction Curves for Total Fauna at the Effluent, Manomet Point, and Rocky Point Stations, October 1991.

3.1.6 Community Analysis

Similarity Analysis by Station

Similarity between stations was measured with two clustering methods, Bray-Curtis and NESS (Grassle & Smith, 1976; Boesch, 1977). Figures 6 and 7 show the dendrograms resulting from the analysis of the spring and fall 1991 data combined. With Bray-Curtis, the two main clusters in the dendrogram represent the two seasons (Figure 6) joining at a low similarity level of 0.21. Within the spring data, there are three large clusters consisting of a mixture of Manomet Point and Rocky Point samples, the remaining three Rocky Point samples, and all Effluent samples, respectively. The similarity among the individual Effluent replicates is the highest of all spring clusters, but the group of Effluent samples joins the two reference samples at a relatively low similarity level of 0.44. In the fall half of the dendrogram, four clusters can be distinguished. They consist of all Manomet Point samples, three Effluent samples, all Rocky Point samples, and the remaining two Effluent samples, respectively. The larger Effluent cluster joins the Manomet Point cluster at the 0.58 level, whereas the small Effluent cluster joins the Rocky Point cluster at the 0.52 level. Similarity among samples forming a cluster is generally lower in the fall than in the spring, but all fall samples join at a level similar to that found in the spring (0.44).

With NESS, which is more sensitive to rare species than Bray-Curtis, the samples group differently in some places (Figure 7). While the fall samples form one large cluster, the spring samples are split into two very dissimilar clusters, one consisting of all samples from the two reference stations (left side of the dendrogram) and the other consisting of the Effluent samples (right side of the dendrogram). The very low similarity of the Effluent station and the reference stations in the spring was already shown in the previous report (BECo, 1991b), and in this combined dendrogram is even more conspicuous because the spring samples from the Effluent station join all other samples taken in spring and fall 1991 at a low level of 0.50, whereas the fall samples join the spring samples from the reference stations at a much higher level of 0.74. That means that the spring Effluent samples are the most dissimilar of all regardless of season. Within the fall cluster, the Effluent samples are split into two groups as in the Bray Curtis analysis. One group joins one of the reference stations similar to the pattern seen in the Bray-Curtis dendrogram. The smaller Effluent cluster does not join the other reference station as seen in the Bray-Curtis dendrogram (Fig. 6), but rather joins all remaining fall samples at the 0.79 level.

The main differences between the Bray-Curtis and NESS dendrograms are as follows: (1) The reference stations group by station with NESS, but form a mixed cluster and one with the remaining Rocky Point samples with Bray-Curtis; (2) the spring Effluent cluster joins the spring reference station clusters with Bray-Curtis, but joins only the combined spring and fall samples with NESS; (3) the fall Effluent samples are

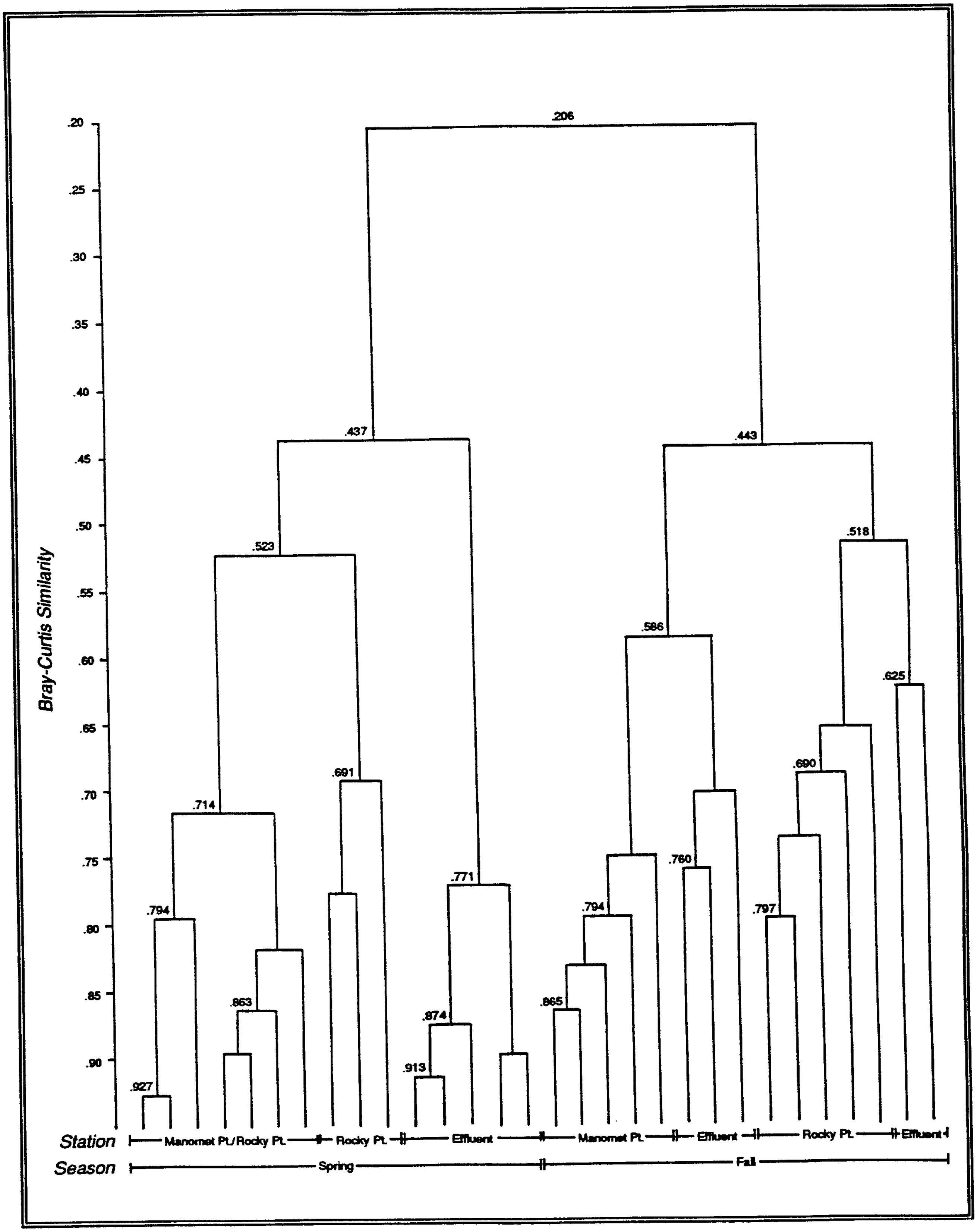

Figure 6. Similarity Analysis Based on Bray-Curtis and Group Average Sorting, Spring and Fall 1991 Data Combined.

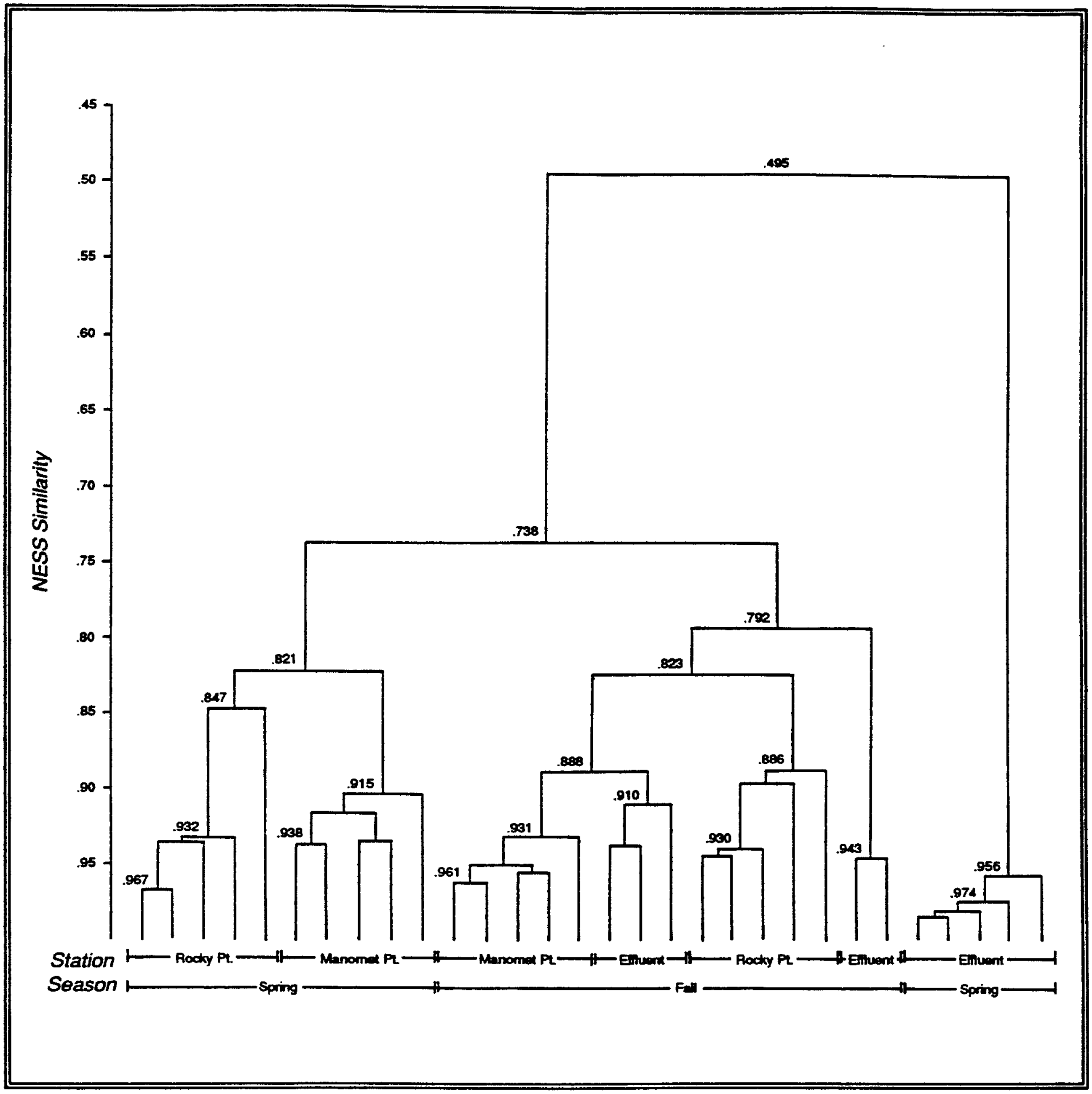

Figure 7. Similarity Analysis Based on NESS and Group Average Sorting, Spring and Fall 1991 Data Combined.

split into two clusters that each join one of the reference stations with Bray-Curtis, but the smaller Effluent cluster joins all other fall samples with NESS. Both methods clearly point at seasonal differences in similarity, and both methods show that the Effluent station is more similar to the reference stations in October 1991 than it has been since September 1990 (see Figure 10 in BECo, 1991a).

Similarity Analysis by Species

The fifty most abundant species of the combined spring and fall 1991 samples were analyzed with Bray-Curtis. The dendrogram is shown in Figure 8, and a list of species groups (clusters) is provided in Table 9. The dendrogram shows two main groups of clusters joining at a similarity level of 0.13 and a single species (the polychaete *Pholoe minuta*) joining all other species at the very low level of 0.09. The two main groups consist of non-dominant species (left side of the dendrogram) and dominant species (right side of the dendrogram). Within these two main clusters, a total of thirteen species groups was identified. Groups 1, 4, 5, 7, 8, and 9 consist of species occurring in low abundances throughout the area during both seasons. Groups 2, 3, and 6 include species that generally occurred in low abundances, but were occasionally found among the dominants. Groups 10, 11, and 12 consist of species that were usually among the dominants at each station during both seasons. Group 13, the single species joining the other 49 species at a very low similarity level, was a spring dominant at the Effluent but otherwise was rare or absent.

Nodal Analysis

To better understand the results of the similarity analyses, the sample groups and species groups were compared in a nodal analysis. Two measures were calculated: constancy, which shows the frequency of occurrences of a species group in a sample group compared to its frequency at all samples combined; and fidelity, which shows how restricted or faithful a species group is to a sample group. The highest possible constancy value is 1.00, indicating that all species of a species group occurred in all samples of a sample group; the lowest possible value is 0, indicating that none of the species in a species group occurred in any of the samples of a sample group. Fidelity values are between 0 (all species of a species group are evenly distributed over all sample groups) and >3 (all species of a species group occurred in only one sample group). The results of the nodal analysis are presented in Figures 9 through 12. In Figures 9 and 10, the dendrograms shown in Figures 6 and 8 are used. The species groups are listed in Table 9, and the sample groups are the ones described in Section 3.1.6.

Figure 9 shows the constancy diagram, with the species groups along the y-axis and the sample groups along the x-axis. Figure 10 shows the corresponding fidelity diagram. There are two questions that can be

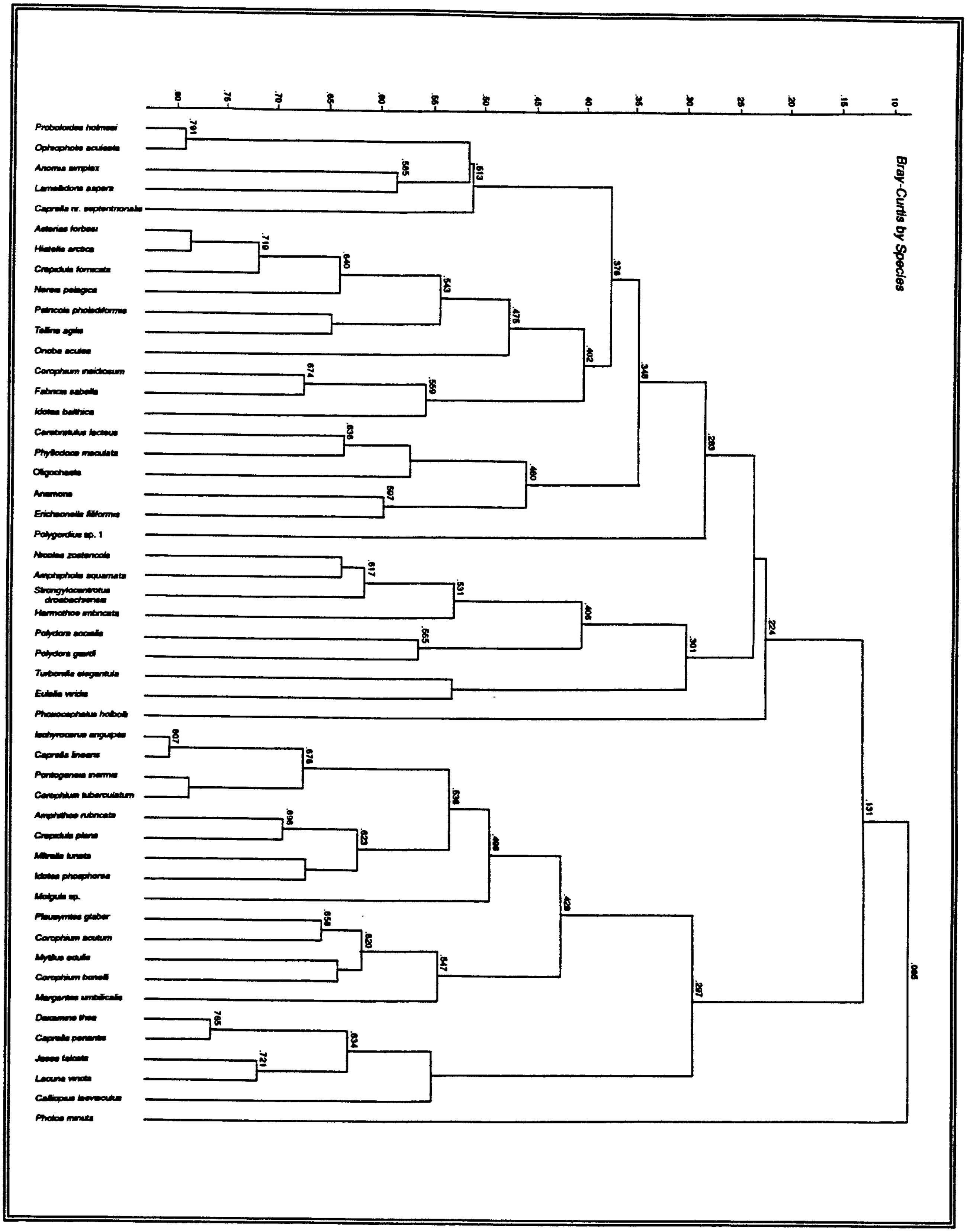

Figure 8. Similarity Analysis of the Fifty Most Abundant Species, Spring and Fall 1991 Data Combined, Using Bray-Curtis and Group Average Sorting.

Table 9. **Species Groups Resulting from the Inverse Cluster Analysis with Bray-Curtis and Group Average Sorting.**

Group 1
- *Proboloides holmesi*
- *Ophiopholis aculeata*
- *Anomia simplex*
- *Lamellidoris aspera*
- *Caprella* nr. *septentrionalis*

Group 2
- *Asterias forbesi*
- *Hiatella arctica*
- *Crepidula fornicata*
- *Nereis pelagica*
- *Petricola pholadiformis*
- *Tellina agilis*
- *Onoba aculea*

Group 3
- *Corophium insidiosum*
- *Fabricia sabella*
- *Idotea balthica*

Group 4
- *Cerebratulus lacteus*
- *Phyllodoce maculata*
- Oligochaeta
- Anemone
- *Erichsonella filiformis*

Group 5
- *Polygordius* sp. 1

Group 6
- *Nicolea zostericola*
- *Amphipholis squamata*
- *Strongylocentrotus droebachiensis*
- *Harmothoe imbricata*

Group 7
- *Polydora socialis*
- *Polydora giardi*

Group 8
- *Turbonilla elegantula*
- *Eulalia viridis*

Group 9
- *Phoxocephalus holbolli*

Group 10
- *Ischyrocerus anguipes*
- *Caprella linearis*
- *Pontogeneia inermis*
- *Corophium tuberculatum*
- *Amphithoe rubricata*
- *Crepidula plana*
- *Mitrella lunata*
- *Idotea phosphorea*
- *Molgula* sp.

Group 11
- *Pleusymtes glaber*
- *Corophium acutum*
- *Mytilus edulis*
- *Corophium bonelli*
- *Margarites umbilicalis*

Group 12
- *Dexamine thea*
- *Caprella penantis*
- *Jassa falcata*
- *Lacuna vincta*
- *Calliopius laevisculus*

Group 13
- *Pholoe minuta*

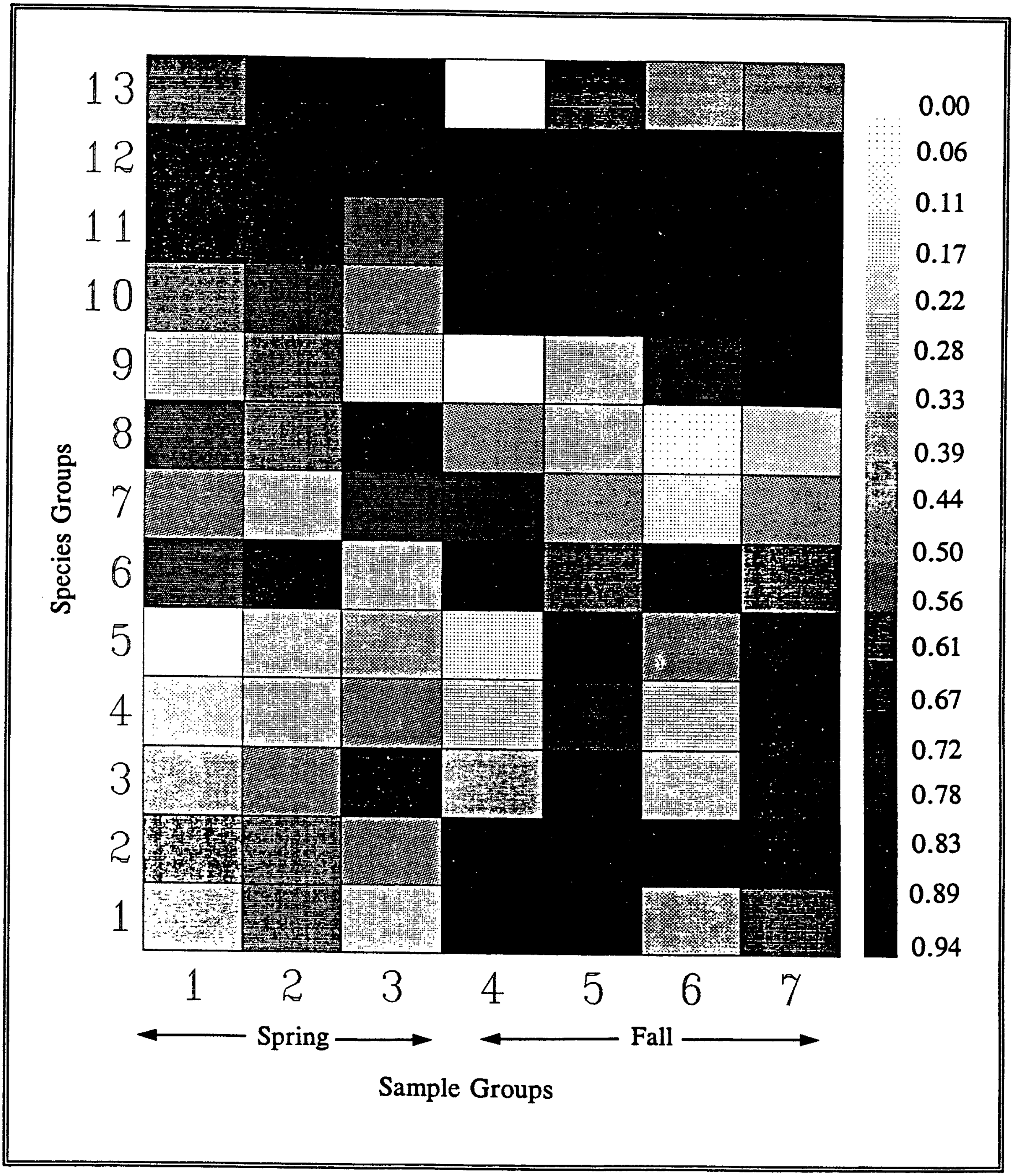

Figure 9. Constancy Diagram for Species Groups and Sample Groups in 1991. Clustering is with Bray-Curtis and Group Average Sorting.

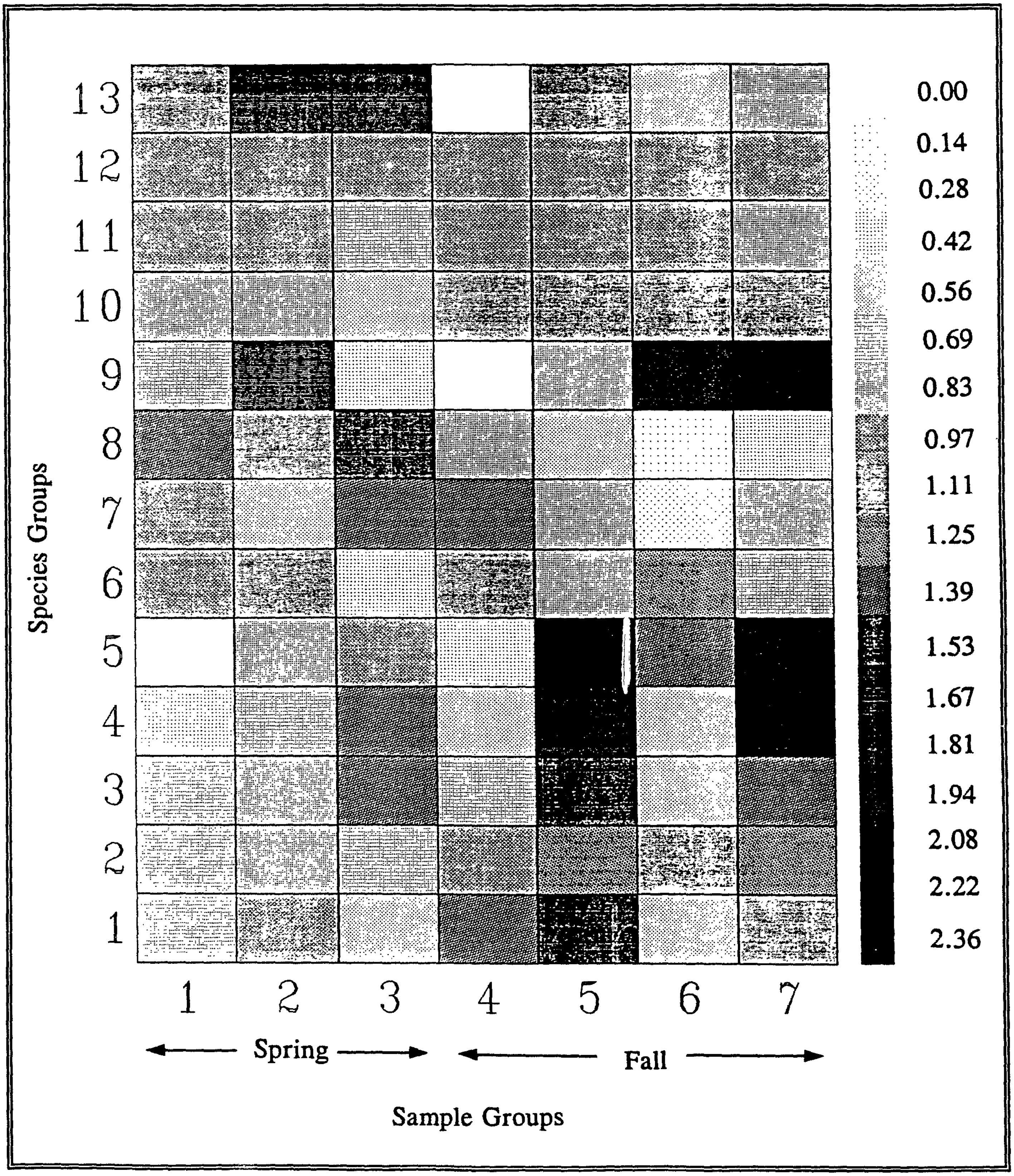

Figure 10. Fidelity Diagram for Species Groups and Sample Groups in 1991. Clustering is with Bray-Curtis and Group Average Sorting.

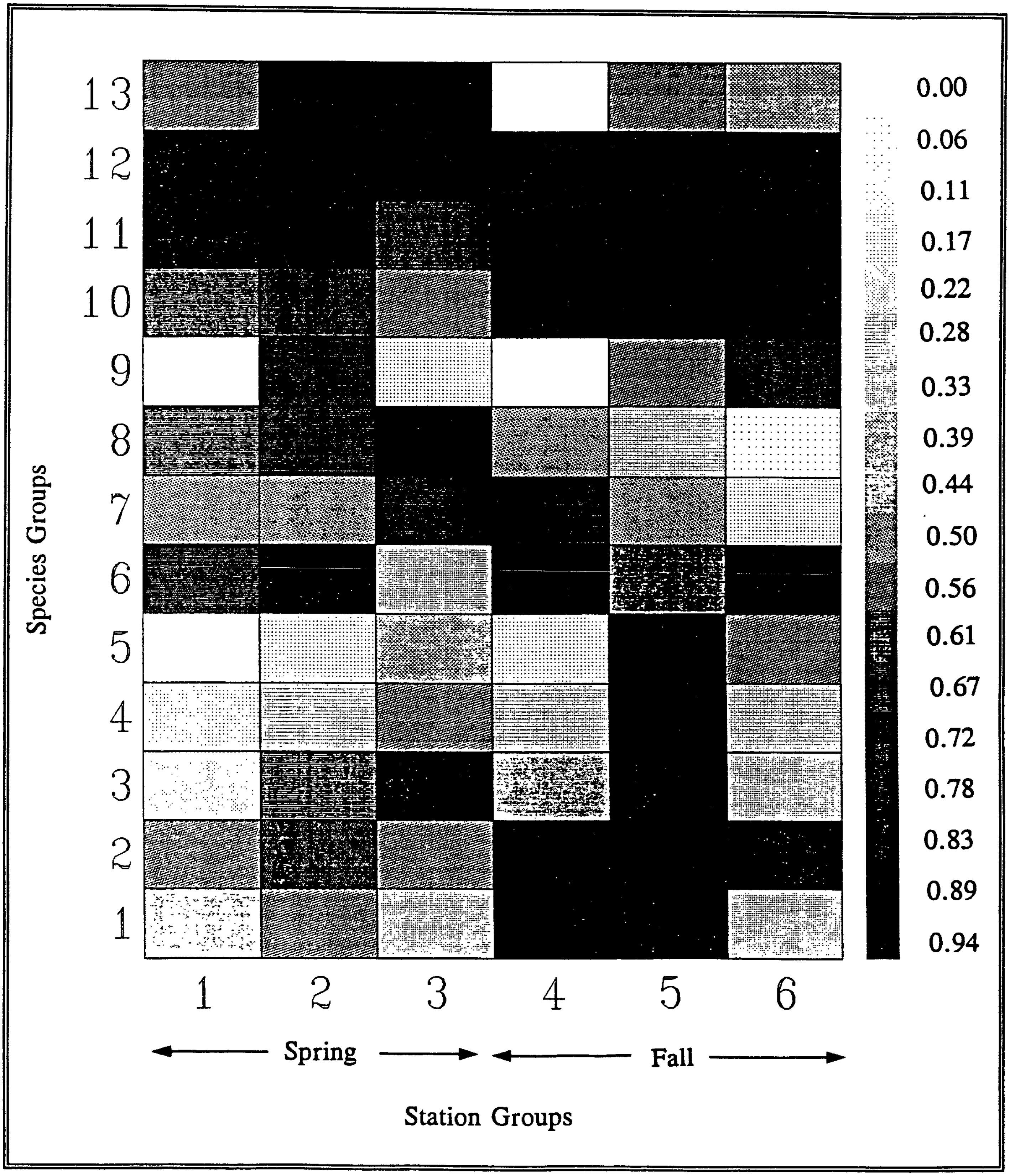

Figure 11. Constancy Diagram for Species Groups and Station Groups in 1991. Clustering is with Bray-Curtis and Group Average Sorting.

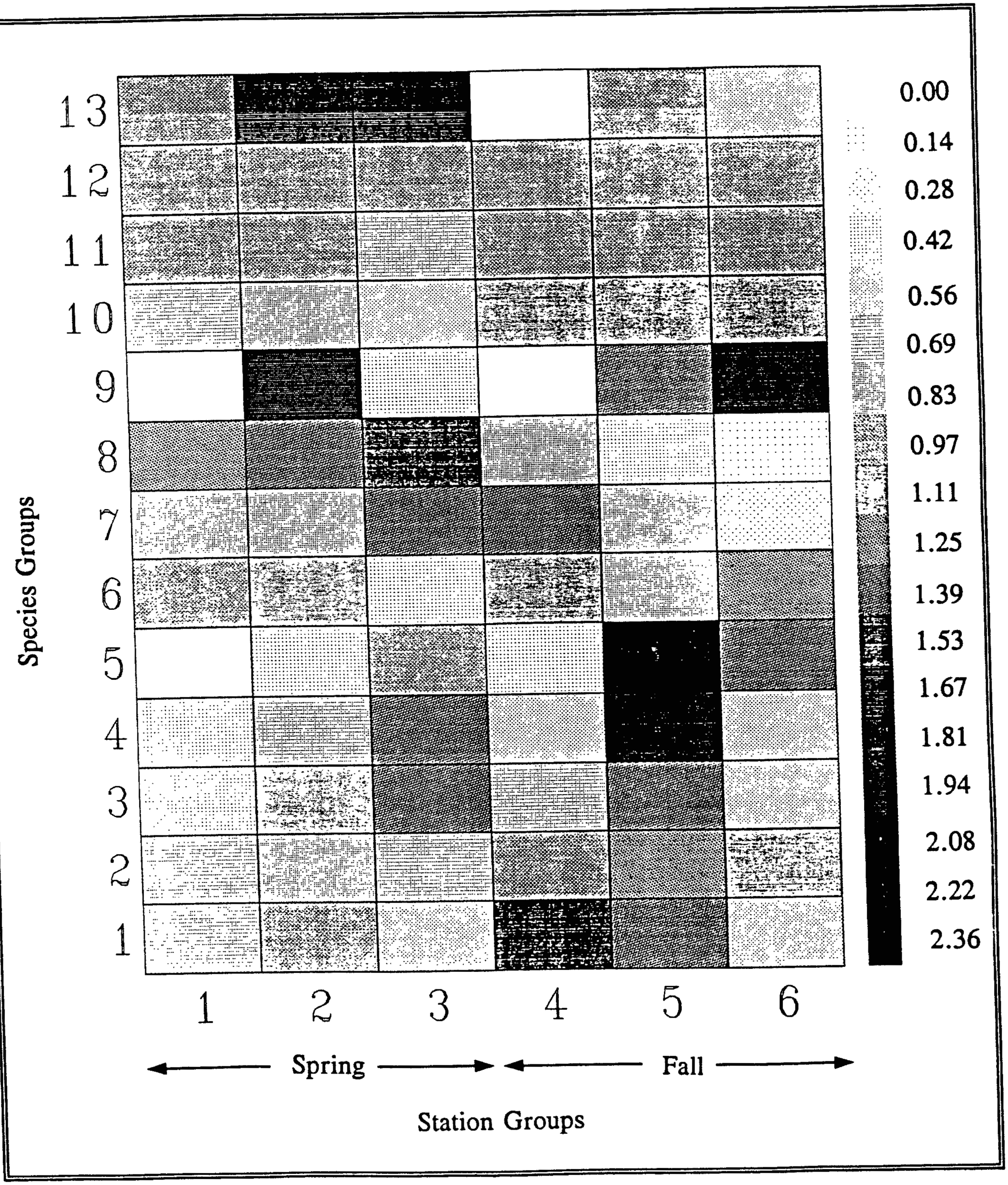

Figure 12. Fidelity Diagram for Species Groups and Station Groups in 1991. Clustering is with Bray-Curtis and Group Average Sorting.

answered with the help of these two measures: (1) why was the Effluent station so dissimilar to the reference stations in the spring (especially visible in the NESS dendrogram where it appeared as the most dissimilar station of both seasons)? and (2) why do the fall samples from the Effluent station split into two dissimilar clusters? To answer the first question, those species groups have to be identified that have constancy and/or fidelity values in sample group 3 (spring Effluent samples) differing considerably from the values with all other sample groups. Those species groups are group 11 among the dominants (including *Mytilus edulis*) and groups 6 and 8 among the non-dominants. Both groups 6 and 11 exhibit a much lower constancy and fidelity in sample group 3 than in any other sample group, whereas species group 8 has much higher constancy and fidelity values in this species group than in any other.

The formation of the two fall Effluent clusters (sample groups 5 and 7) is chiefly caused by differences in constancy and fidelity of species groups 1 and 9 that exhibit a patchy distribution. Abundances of the species forming group 1 are generally higher in sample group 5 (3 Effluent fall samples) than in sample group 7 (2 Effluent fall samples). Species group 9, which consists only of the amphipod *Phoxocephalus holbolli*, is less abundant in sample group 5 than in sample group 7.

Figures 11 and 12 show constancy and fidelity diagrams that resulted from a comparison of the species groups listed in Table 9 and 6 sample groups, each consisting of all replicates of one station from one season. This analysis was performed to detect those species that caused the clear seasonal break in both the Bray-Curtis and NESS dendrograms (Figures 6 and 7). Four species groups showed similar seasonal differences at all stations: groups 8 and 13 had higher constancy and fidelity values in all spring samples (sample groups 3-6), whereas species groups 2 and 10 had higher constancy and fidelity values in the fall (sample groups 4-6). Species group 10 is the only group that includes dominant species, whereas all other groups responsible for the seasonal differences consist of non-dominant species. In addition, there are station-specific seasonal differences in constancy and fidelity of other species groups that may have contributed to the overall seasonal differences.

3.2 QUANTITATIVE ALGAL MONITORING

3.2.1 Systematics

No additions to the cumulative algal species list presented in Semi-Annual Report No. 16 (BECo, 1980) were made as a result of the analyses of the March or October 1991 samples. The 27 species found in 1991 samples are indicated in Table 1.

3.2.2 Algal Community Description

The habitats and associated algal and faunal communities found at the Manomet Point, Rocky Point, and Effluent subtidal stations are typical of shallow, exposed areas in western Cape Cod Bay and have been well documented by Grocki (1984) and Davis and McGrath (1984). The rocky substrata characteristic of all three stations are covered with dense macroalgal communities typically dominated by two species, *Chondrus crispus* and *Phyllophora* spp. In 1991, red macroalgae moderately colonized the rock and cobble substrata found at all three stations. Two-thirds of the species collected in March and three-quarters of the species collected in October belonged to the Rhodophyta (red algae). In addition to the dominant species *Chondrus crispus* and *Phyllophora* spp., other benthic rhodophytes included *Corallina officinalis*, present in all March replicates, *Polysiphonia urceolata* and *Rhodomela confervoides*, present in all October replicates, as well as *Ahnfeltia plicata* and *Polyides rotundus*. Epiphytic rhodophytes found in all March and October replicate samples were *Ceramium rubrum*, *Cystoclonium purpureum*, and *Spermothamnion repens*. Other species collected in all March and October samples were the chlorophytes (green algae) *Chaetomorpha linum*, *C. melagonium* and *Rhizoclonium riparium*; and the phaeophyte (brown alga) *Desmarestia aculeata*. Three alga species seen in the March samples were absent in the fall collections, the chlorphyte *Cladophora* spp., and the phaeophytes *Desmarestia viridis* and *Sphacelaria cirrosa*.

Biomass of *Chondrus crispus* was highest at Manomet Point in March and October. Biomass of *Phyllophora* spp. was highest at Rocky Point in March and at the Effluent station in October. The highest biomass of the remaining benthic species was at the Rocky Point station in both March and October. Manomet Point had the highest biomass of epiphytic algae in March but the lowest in October. *Gracilaria tikvahiae*, an indicator of warm water, was not collected in any of the replicate samples in either March or October 1991. However, *Gracilaria* was observed by the divers within the discharge canal during all four seasons; *Gracilaria*, within the denuded zone, extended out to 40 m on the transect line in March, and was densest within the discharge canal in October. No *Laminaria*, a cold water indicator, was seen at the Effluent station at any season; *Laminaria* was observed at both reference stations in March and at Rocky Point in October.

3.2.3 Algal Community Overlap

Community overlap was calculated for March and October 1991 using Jaccard's coefficient (Grieg-Smith, 1964) to provide a mathematical evaluation of the similarity in algal composition between pairs of replicates or staions. Jaccard's coefficient uses only species occurrence and is not influenced by differences in abundance. Species occurrence records of the 27 indicator species found in 1991 (Table 1) were used for these calculations.

Comparisons between replicate samples for each station for March and October 1991 are presented in matrix form in Figures 13 and 14. Overall, the similarity of all three stations was high, ranging from 81.5% to 88.5% in March and from 83.3% to 90.5% in October, indicating a high degree of homogeneity in algal species present at all three stations. In March, community overlap between the Effluent station and both Manomet Point and Rocky Point was higher (88.5% and 84.6%, respectively) than between the two reference stations (81.5%), indicating that the algal communities at the reference stations were more similar to the algal community at the Effluent station than they were to each other. However, the situation had reversed by the fall when community overlap between the Effluent station and both Manomet Point and Rocky Point was lower (83.3%, in both cases) than between the two reference stations (90.5%), indicating that the algal communities at the reference stations were more similar to each other than they were to the Effluent station. Community overlap between Manomet Point and Rocky Point increased from March (81.5%) to October (90.5%), showing that the algal communities at Manomet Point and Rocky Point were more similar to each other in October than in March. Concurrently, from March to October, overlap between the Effluent Station and each of the reference stations decreased, evidence that by the fall the Effluent station was less similar to the reference stations than it had been March.

The range in percent overlap between replicates at the Effluent station was slightly higher in March (19.7%) than in October (16.8%), suggesting that the replicates were more similar in the fall than in the spring. A much larger seasonal difference was seen at the reference stations. At both the Manomet Point and Rocky Point stations the range in percent overlap between replicates was much greater in March (25.0% and 21.7%, respectively) than in October (15.8% at both stations), a trend also seen in 1990. This indicates that in October the replicate samples from the reference stations were much more similar to each other than those taken in March.

A

	1	2	3	4	5
1		21	25	21	21
2	84.0		21	19	19
3	100.0	84.0		21	21
4	84.0	82.6	84.0		18
5	84.0	82.6	84.0	75.0	

Percent Overlap / Number of Species Shared

C

	1	2	3	4	5
1		17	18	19	17
2	73.9		17	16	15
3	78.3	77.3		19	17
4	82.6	66.7	86.4		17
5	81.0	71.4	85.0	81.0	

Percent Overlap / Number of Species Shared

B

	1	2	3	4	5
1		19	16	21	19
2	82.6		17	21	19
3	69.6	77.3		17	18
4	91.3	91.3	70.8		20
5	82.6	82.6	85.7	83.3	

Percent Overlap / Number of Species Shared

D

	MP	RP	EFF
MP		22	23
RP	81.5		22
EFF	88.5	84.6	

Percent Overlap / Number of Species Shared

Figure 13. Algal Community Overlap (Jaccard's Coefficient of Community) and Number of Species Shared Between Replicate Pairs, March 1991. A, Manomet Point Station; B, Rocky Point Station; C, Effluent Station; D, Station Overlap.

	1	2	3	4	5
1		15	15	15	15
2	83.3		18	17	17
3	78.9	94.7		17	17
4	83.3	89.5	85.0		17
5	88.2	94.4	89.5	94.4	

Percent Overlap

Number of Species Shared

A

	1	2	3	4	5
1		17	17	16	17
2	81.0		17	17	18
3	73.9	73.9		16	18
4	80.0	89.5	72.7		16
5	77.3	85.7	78.3	76.2	

Percent Overlap

Number of Species Shared

B

	1	2	3	4	5
1		16	17	17	17
2	84.2		17	17	17
3	94.4	89.5		18	18
4	89.5	85.0	94.7		18
5	94.4	89.5	100.0	94.7	

Percent Overlap

Number of Species Shared

C

	MP	RP	EFF
MP		19	20
RP	90.5		20
EFF	83.3	83.3	

Percent Overlap

Number of Species Shared

D

Figure 14. Algal Community Overlap (Jaccard's Coefficient of Community) and Number of Species Shared Between Replicate Pairs, October 1991. A, Manomet Point Station; B, Rocky Point Station; C, Effluent Station; D, Station Overlap.

3.2.4 Algal Biomass

Chondrus crispus

Chondrus crispus biomass was measured at the Effluent, Manomet Point, and Rocky Point stations in March and October 1991 (Tables 10 and 11, respectively). In March, the range of individual biomass values was highest at Rocky Point (2.75 to 277.33 g/m^2), followed by the Effluent station (0.46 to 146.24 g/m^2), and Manomet Point (82.44 to 217.75 g/m^2). At the Effluent, Manomet Point, and Rocky Point stations, mean *Chondrus* biomass was 21%, 46%, and 35% of the total algal biomass, respectively. The Manomet Point station had the highest mean biomass value for *Chondrus* (161.75 g/m^2), followed by Rocky Point (112.75 g/m^2), and the Effluent station (52.22 g/m^2). An ANOVA showed no significant differences among any of the stations when mean *Chondrus* biomass values were compared (at $p=0.05$).

In October, the range of individual biomass values was greatest at Manomet Point (140.18 to 375.46 g/m^2), followed by the Effluent station (2.48 to 216.83 g/m^2), and Rocky Point (0.00 to 175.52 g/m^2). Mean *Chondrus* biomass was 17%, 41%, and 18% of the total algal biomass, respectively, at the Effluent, Manomet Point, and Rocky Point stations. The Manomet Point station had the highest mean biomass value for *Chondrus* (238.50 g/m^2), followed by the Effluent station (90.09 g/m^2), and Rocky Point (81.17 g/m^2). An ANOVA showed a significant difference among the three stations in *Chondrus crispus* biomass ($F_s=4.78$; $F_{.05[2,12]}=3.89$); however, this difference was so marginal that Scheffé's multiple comparison test was unable to show any difference between means. The Scheffé test indicated that for *Chondrus* biomass, the Effluent station was not different from the reference stations whether considered separately or together and that the two reference stations were not different from each other.

Between March and October the mean biomass of *Chondrus* increased at the Effluent station and Manomet Point and decreased at Rocky Point.

Phyllophora spp.

Phyllophora spp. biomass values for March and October are given in Tables 10 and 11, respectively. In March, the range of individual biomass values was greatest at the Rocky Point station (13.31 to 210.96 g/m^2), followed by the Effluent station (19.19 to 214.63 g/m^2), and Manomet Point (57.74 to 159.55 g/m^2). *Phyllophora* spp. were 51% of the total algal biomass at the Effluent station, 30% at Manomet Point, and 41% at Rocky Point. Rocky Point had the highest mean biomass value for *Phyllophora* spp. (131.07 g/m^2), followed by the Effluent station (127.82 g/m^2), and Manomet Point (105.77 g/m^2). No significant differences existed between the stations in March 1991 when comparing *Phyllophora* spp. biomass (at $p=0.05$).

TABLE 10. Dry Weight Biomass (g/m^2) for *Chondrus crispus*, *Phyllophora* spp., The Remaining Benthic Species, Epiphytes, and Total Algal Biomass at the Effluent, Manomet Point, and Rocky Point Stations in March 1991.

Station/ Replicate	*Chondrus crispus*		*Phyllophora* spp.		Remaining Benthic Species		Epiphytic Species (Total)		All Algae
	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass
EFF 1	7.99	2.81	214.63	75.35	46.63	16.37	15.61	5.48	284.86
EFF 2	49.57	31.09	19.19	12.02	69.86	43.81	20.84	13.07	159.46
EFF 3	146.24	48.88	87.49	29.24	57.65	19.27	7.80	2.61	299.18
EFF 4	0.46	0.22	161.11	78.32	35.43	17.22	8.72	4.24	205.72
EFF 5	56.82	19.22	156.70	52.99	63.80	21.58	18.36	6.21	295.69
$\bar{x}$ EFF	52.22	20.97	127.82	51.34	54.67	21.96	14.27	5.73	248.98
MP 1	183.97	40.99	159.55	35.55	43.70	9.74	61.60	13.72	448.82
MP 2	217.75	60.65	103.00	28.69	12.76	3.55	25.52	7.11	359.03
MP 3	82.44	27.23	144.13	47.61	17.99	5.94	58.20	19.22	302.76
MP 4	176.62	53.91	57.74	17.62	23.32	7.12	69.95	21.35	327.63
MP 5	147.98	43.89	64.44	19.11	41.22	12.22	83.54	24.78	337.18
$\bar{x}$ MP	161.75	45.55	105.77	29.79	27.80	7.83	59.76	16.83	355.08
RP 1	277.33	84.46	13.31	4.05	22.40	6.82	15.33	4.67	328.37
RP 2	63.34	19.83	181.30	56.75	59.39	18.59	15.42	4.83	319.46
RP 3	173.59	61.10	45.53	16.02	46.08	16.22	18.91	6.66	284.12
RP 4	2.75	0.80	204.26	59.56	102.27	29.82	33.69	9.82	342.96
RP 5	46.73	13.90	210.96	62.74	60.13	17.88	18.45	5.49	336.26
$\bar{x}$ RP	112.75	34.99	131.07	40.68	58.05	18.02	20.36	6.32	322.23

EFF: Effluent; MP: Manomet Point; RP: Rocky Point; $\bar{x}$: Mean biomass

TABLE 11. Dry Weight Biomass (g/m^2) for *Chondrus crispus*, *Phyllophora* spp., The Remaining Benthic Species, Epiphytes, and Total Algal Biomass at the Effluent, Manomet Point, and Rocky Point Stations in October 1991.

Station/ Replicate	*Chondrus crispus*		*Phyllophora* spp.		Remaining Benthic Species		Epiphytic Species (Total)		All Algae
	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass
EFF 1	36.17	4.77	470.84	62.03	4.87	0.64	247.13	32.56	759.01
EFF 2	19.09	4.60	269.16	64.83	9.64	2.32	117.32	28.26	415.21
EFF 3	2.48	0.46	408.14	75.08	33.97	6.25	99.05	18.22	543.64
EFF 4	216.83	53.16	122.00	29.91	14.60	3.58	54.44	13.35	407.87
EFF 5	175.89	32.65	250.16	46.44	42.41	7.87	70.23	13.04	538.68
$\bar{x}$ EFF	90.09	16.91	304.06	57.06	21.10	3.96	117.63	22.07	532.88
MP 1	375.46	74.65	79.87	15.88	3.49	0.69	44.15	8.78	502.97
MP 2	294.04	44.02	324.42	48.57	7.89	1.18	41.59	6.23	667.94
MP 3	197.46	26.94	436.51	59.56	17.81	2.43	81.06	11.06	732.84
MP 4	185.34	38.76	234.82	49.11	4.68	0.98	53.33	11.15	478.17
MP 5	140.18	26.57	323.87	61.39	7.34	1.39	56.18	10.65	527.57
$\bar{x}$ MP	238.50	40.99	279.90	48.10	8.24	1.42	55.25	9.49	581.90
RP 1	10.47	2.37	85.19	19.29	140.91	31.90	205.17	46.45	441.74
RP 2	0.00	0.00	159.64	31.90	163.40	32.65	177.45	35.46	500.49
RP 3	90.70	20.80	112.27	25.74	82.07	18.82	151.11	34.65	436.15
RP 4	175.52	36.23	145.14	29.96	80.97	16.71	82.80	17.09	484.43
RP 5	129.16	29.27	76.56	17.35	88.77	20.12	146.79	33.26	441.28
$\bar{x}$ RP	81.17	17.61	115.76	25.12	111.22	24.14	152.66	33.13	460.82

EFF: Effluent; MP: Manomet Point; RP: Rocky Point; $\bar{x}$: Mean biomass

In October, the greatest range of individual biomass values was at Manomet Point ((79.87 to 436.51 g/m²), followed by the Effluent station (122.00 to 470.84 g/m²), and Rocky Point (76.56 to 159.64 g/m²). *Phyllophora* spp. made up approximately one-half of the total algal biomass at the Effluent and Manomet Point stations (57% and 48%, respectively), but only one-quarter of the total biomass at Rocky Point (25.0%). The Effluent station had the highest mean biomass for *Phyllophora* spp. (304.06 g/m²), followed by Manomet Point (279.90 g/m²), and Rocky Point (115.76 g/m²). An ANOVA showed a significant difference among the three stations in *Phyllophora* spp. biomass (F_s=4.15; $F_{.05[2,12]}$=3.89). However, just as in the case with *Chondrus*, this difference was so slight that the Scheffé's multiple comparison test was unable to show where this difference occurred; the Scheffé test showed that the reference stations were not different from each other and that the Effluent station was not different from the reference stations.

The typical seasonal increase of *Phyllophora* spp. biomass from spring to fall (BECo, 1987a) did occur at the Effluent station and Manomet Point where the mean biomass more than doubled; however, at Rocky Point, mean biomass decreased, so that Rocky Point which had had the greatest *Phyllophora* biomass in March had the least in October.

Biomass of Remaining Benthic Species

The category called "remaining benthic species" excludes *Chondrus crispus*, *Phyllophora* spp., and algal epiphytes, but does include *Chaetomorpha linum*, *C. melagonium*, *Rhizoclonium riparium*, *Ahnfeltia plicata*, and *Polyides rotundus* at all stations during both seasons, and *Phycodrys rubens* at all stations in the spring and the Effluent station in the fall.

Biomass data for the remaining benthic species for March and October 1991 are presented in Tables 10 and 11. In both March and October, Rocky Point had the greatest range of biomass values (79.87 and 82.43 g/m², respectively), followed by the Effluent station (34.43 and 37.54 g/m², respectively) and Manomet Point (30.94 and 14.32 g/m², respectively). In March, the percentage that the remaining benthic species contributed to the total algal biomass was greatest at the Effluent station (22%), intermediate at Rocky Point (18%), and least at Manomet Point (8%); in October, Rocky Point had the largest percentage of remaining benthic species (24%), followed by the Effluent station (4%), and Manomet Point (1%). The highest mean biomass values occurred at Rocky Point in both spring and fall (58.05 and 111.22 g/m², respectively); the Effluent station had intermediate biomass values during both seasons (54.67 and 21.10 g/m², respectively) and Manomet Point had the smallest values (27.80 and 8.24 g/m², respectively).

To avoid statistical redundancy and permit a meaningful ANOVA for the total algal biomass, an ANOVA for biomass of the remaining benthic species is not presented here. Furthermore, in October, an examination of the variance (the F_{max}-test) calculated from biomass values for the remaining benthic species showed that the data were not homogeneous ($s^2_{max}/s^2_{min}=45.97$; $F_{max.05[3,4]}=15.5$; $F_{max}^{.01[3,4]}=37.00$), even at $P<0.10$ and, therefore, could not be used in an ANOVA as they do not satisfy one of the basic assumptions for an ANOVA.

Epiphytic Algal Biomass

Biomass values of epiphytic algae in March and October 1991 are given in Tables 10 and 11. In March 1991, mean epiphytic biomass values were highest at Manomet Point (59.76 g/m²), followed by Rocky Point (20.36 g/m²), and the Effluent station (14.27 g/m²). In October, mean epiphytic biomass values were highest at Rocky Point (152.66 g/m²), followed by the Effluent station (117.63 g/m²), and Manomet Point (55.25 g/m²). Epiphytic algal biomass at the Effluent station was less than that at Rocky Point in March and October (30% and 23%, respectively). However, the relationship in epiphytic algal biomass between the Effluent station and Manomet Point changed dramatically from spring to fall, reversing from 76% less at the Effluent station in March to 133% more in October. The percent contribution of the epiphytic species to the total algal biomass at Manomet Point was greatest in March (16.83%) but least in October (9%). At the Effluent station and Rocky Point, the epiphytic species contributed a small and similar percentage to the total algal biomass in March (5.73% and 6.32%, respectively) but were a large contributor in October (22% and 33%, respectively).

There was a significant difference among the three stations in epiphytic algal biomass in March ($F_s=16.52$; $F_{.05[2,12]}=3.89$) and October ($F_s=4.48$; $F_{.05[2,12]}=3.89$). Scheffé's multiple comparison test attributed the ANOVA results in both seasons to a significant difference in epiphytic algal biomass at Manomet Point and Rocky Point. In addition, in March, the epiphytic algal biomass at the Effluent station was significantly different from the mean biomass at the reference stations and from the biomass at Manomet Point though not significantly different from the Rocky Point station biomass.

Total Algal Biomass

Values for total algal biomass for March and October 1991 are given in Tables 10 and 11. The Effluent station had the lowest mean biomass value (248.98 g/m²) in March and an intermediate value (532.88 g/m²) in October. Manomet Point had the highest mean biomass value in both March and October (355.08 and 581.90 g/m², respectively). In March, total algal biomass at the Effluent station was 30% less than at Manomet Point and 23% less than at Rocky Point; in October, total algal biomass at the Effluent station was 8% less than at Manomet Point and 16% greater than at Rocky Point. Total algal biomass increased from spring to fall at all three stations, by 43% at Rocky Point, 64% at Manomet Point, and 114% at the Effluent station.

In March, an ANOVA showed a significant difference among the three stations in total algal biomass (F_s=5.78; $F_{.05[2,12]}$=3.89). Scheffé's multiple comparison test showed that total algal biomass at the Effluent station was significantly different from the mean biomass at the reference stations and from the biomass at Manomet Point but was not significantly different from the Rocky Point station biomass, nor were the two reference stations different from each other. In October, an ANOVA showed no significant differences among the three stations in total algal biomass.

3.3 QUALITATIVE TRANSECT SURVEY

Qualitative transect examinations of the acute impact zone were initiated in January 1980 and quarterly surveys were begun in 1982. Four surveys were performed during 1991 (March 28, June 27, October 4, and December 26), bringing the total number of surveys conducted since 1980 to 44. Results of surveys conducted from 1980 through 1983 were summarized in Semi-Annual Report No. 22 (BECo, 1983). A summary of the surveys conducted between 1983 and 1988 is presented in Semi-Annual Report No. 35 (BECo, 1990a), along with a review of the four surveys performed in 1989. Results of the four 1990 surveys are in Semi-Annual Report No. 37 (BECo, 1991a). Detailed results of the March and June 1991 surveys are in Semi-Annual Report No. 38 (BECo, 1991b). This report summarizes the March and June 1991 surveys and incorporates new data from the October and December 1991 surveys.

Figures 15, 16, 17, and 18 show the results of transect surveys performed by SCUBA divers. The denuded zone is essentially devoid of *Chondrus crispus*, the stunted zone contains *Chondrus* that is smaller and less dense than that growing under normal conditions. and the sparse zones are those in which normal looking *Chondrus* is sparsely distributed. The distinction between stunted and sparse zones was initiated this year by the divers. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the Science Applications International Corporation (SAIC) and the Massachusetts Division of Marine Fisheries dive teams, is plotted in each figure. This boulder serves as a visual fix for the proper placement of the transect line and ensures consistency among the surveys.

3.3.1 March 1991 Transect Survey

The extent of the denuded and stunted areas mapped on March 28, 1991 immediately offshore from PNPS is shown in Figure 15. The *Chondrus* denuded zone extended approximately 94 m offshore along the central transect line and was asymmetrically distributed, extending 8 to 13 m northwest and 3 to 4 m southeast

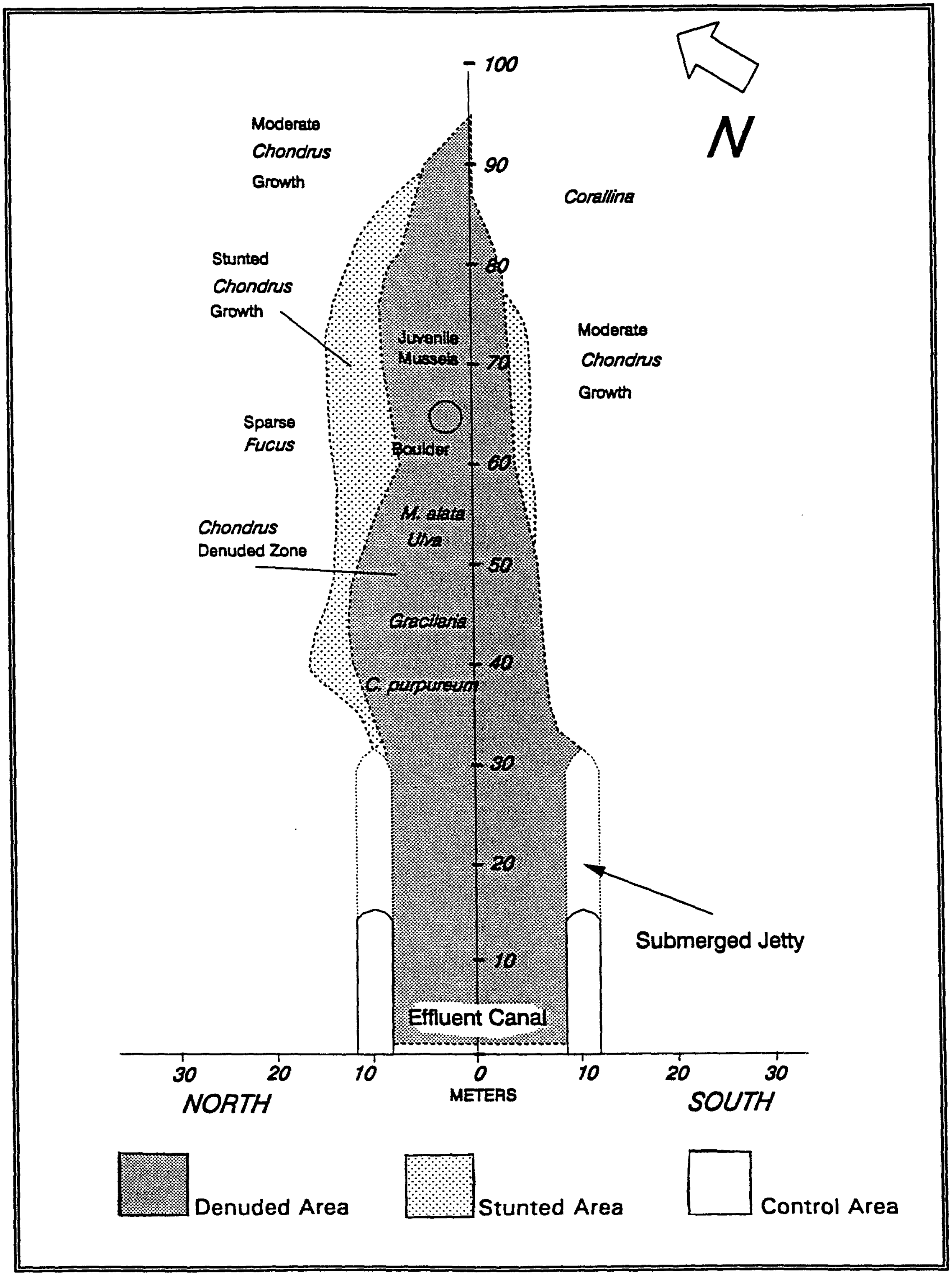

Figure 15. **Stunted and Denuded *Chondrus* Zones Observed in March 1991.**

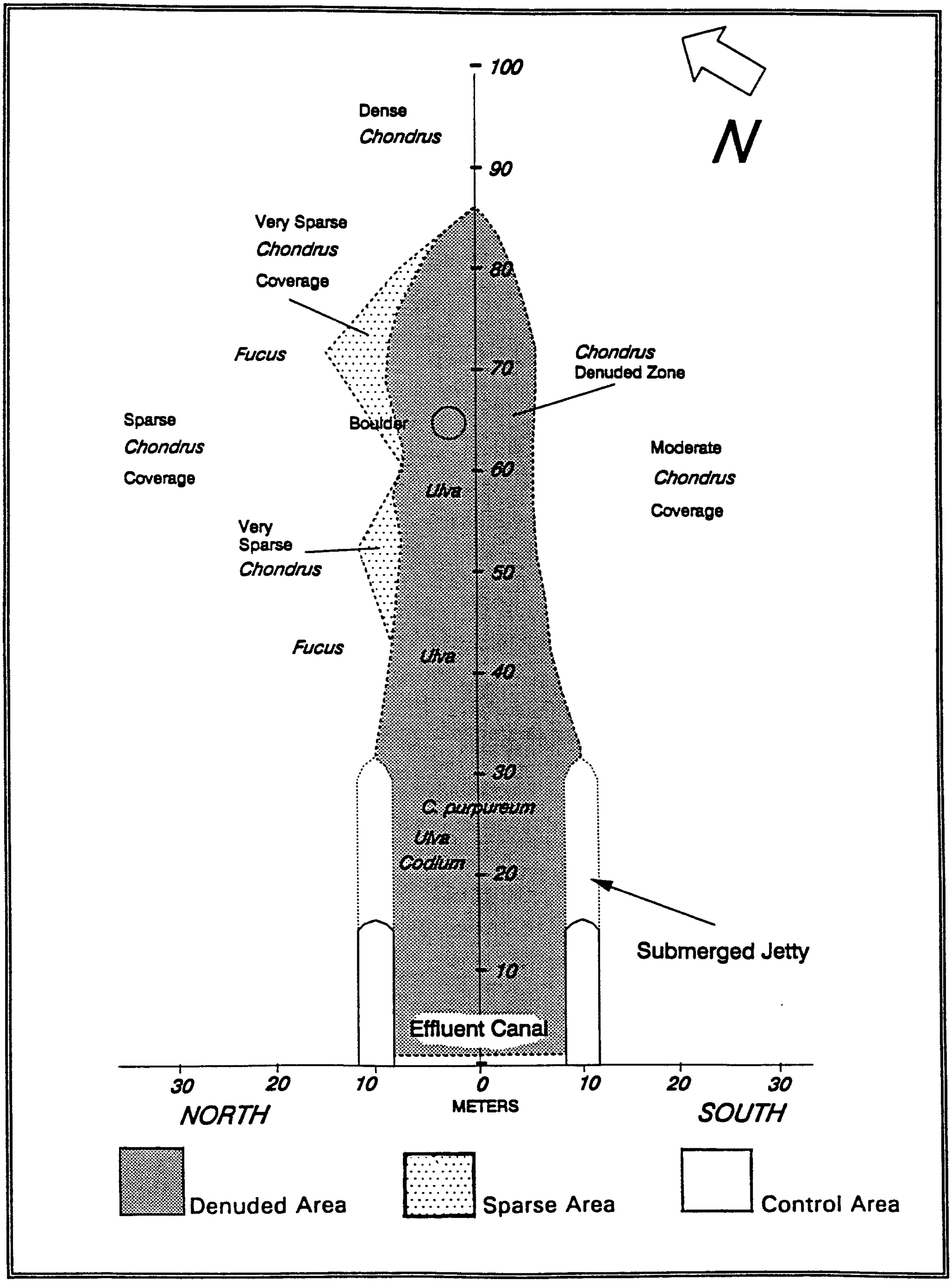

Figure 16. **Sparse and Denuded *Chondrus* Zones Observed in June 1991.**

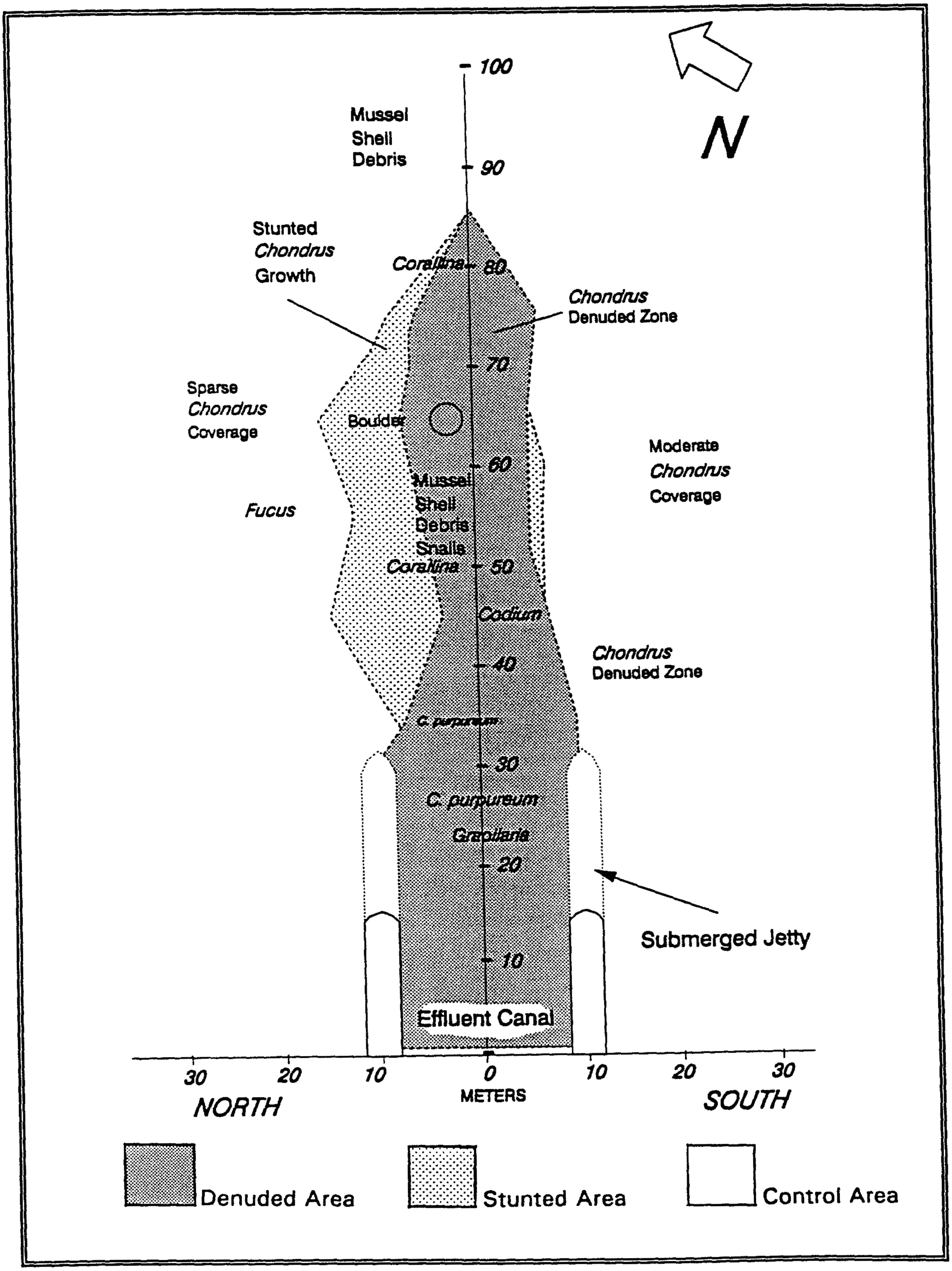

Figure 17. **Stunted and Denuded *Chondrus* Zones Observed in October 1991.**

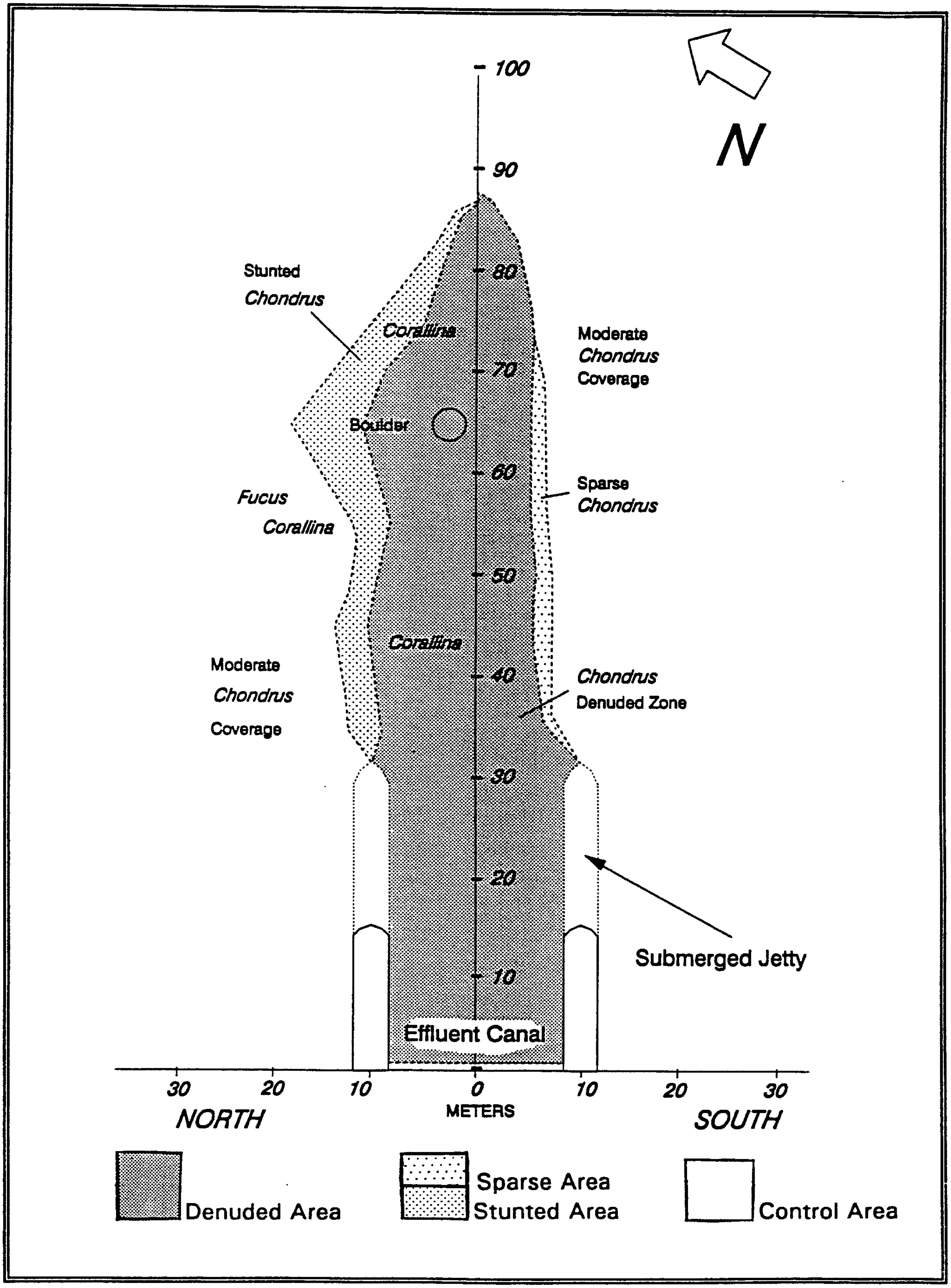

Figure 18. Sparse, Stunted, and Denuded *Chondrus* Zones Observed in December 1991.

of the baseline. The denuded zone covered an area of 1320.5 m², and was 5% larger than in December 1990. Dense assemblages of *Cystoclonium purpureum* and a species tentatively identified as *Gracilaria tikvahiae* were growing near the 40-m mark on the transect line. To the northwest, *Membranoptera alata*, an alga not seen during the two previous surveys, was living near patches of *Ulva lactuca*. Dense patches of mussels (*Mytilus edulis*) had settled on several rocks between the 70 to 80-m marks and within 8 m of the baseline. The stunted zone (225 m²) was 25% larger than in December 1990.

3.3.2 June 1991 Transect Survey

Results of the divers' survey taken on June 27, 1991 are shown in Figure 16. The denuded zone extended 85 m along the transect line, 9 m less than in March, and was slightly asymmetrically distributed around the transect line with more area northwest of the line than southeast of the line. The area of the denuded zone (1265 m²) had decreased slightly from that seen in March 1991. Within the discharge canal there was dense coverage of the red, fibrous alga, *Cystoclonium purpureum* and patches of *Ulva lactuca* and *Codium fragile*. *Ulva* was present within the denuded zone from the jetties to the 70-m mark, north of the transect line. No true region of stunted *Chondrus* growth was observed. Two areas north of the denuded zone contained sparsely distributed but normal looking *Chondrus*; the southern boundary was clearly delineated by moderate coverage of normally growing *Chondrus* and increased algal diversity.

3.3.3 October 1991 Survey

Figure 17 shows the results of the transect survey conducted on October 4, 1991. The denuded zone extended to the 86-m mark on the transect line. The asymmetry of the denuded zone around the transect line with more area denuded of *Chondrus* north of the line (52%) than to the south (48%) was less pronounced than in the March or June surveys. The greatest lateral extent of the denuded zone was 7 m from the transect line at the 65-m mark. The area (1080 m²) of the denuded zone was 13% less than that found in June.

Within the discharge canal, there was thick coverage by a purple-colored, fibrous alga, probably *Cystoclonium purpureum*, and a green, filamentous alga, *Gracilaria*. Beyond the discharge canal, algal species density and diversity was lower north of the transect line than south. Within 10 m north of the transect line most rock surfaces were bare with a scattering of individual (stunted) *Chondrus* plants. *Corallina* appeared as small patches within parts of this region but very few additional species of algae were observed. Further to the north, more than 10 m from the transect line, the flora consisted of *Fucus* spp. and denser arrays of *Chondrus*. The *Chondrus* denuded zone was more clearly delineated on the southern side of the transect line than on the north and ran roughly parallel (5 m offset) to the line; bare rock characterized much of the 5-m area, beyond which *Chondrus* and several other algal species densely covered all rock surfaces. Mussel shell patches were present within 5 to 8 m of the transect line at the 55-m, 75-m, and 95-m marks along the line; these areas corresponded to juvenile mussel beds noted in the March 1991 survey. No *Laminaria* was observed in the area.

The stunted zone (283 m^2), absent in June, reappeared. The stunted zone was very asymmetrically distributed with 95% (269 m^2) of the area north of the transect line. The northern region was characterized by two bulges to the northwest at the 45-m and 65-m marks and reached 14 m and 15 m away from the transect line, respectively. To the south, the stunted zone appeared only as a narrow band, 1 m wide at the most, from the 45-m to 65-m marks.

3.3.4 December 1991 Transect Survey

The results of the divers' survey performed on December 26, 1991 are mapped in Figure 18. The denuded zone extended out to the 87-m mark on the transect line. The asymmetry of the denuded zone around the transect line was more pronounced than in either June or October with the boundary extending out to 10 and 11 m north of the transect line but only 5 m to the south. The area (1200 m^2) of the denuded zone was 11% greater than in the October survey and only slightly less (5%) than it had been in June.

The density of *Gracilaria* and *Cystoclonium purpureum* within the discharge canal was much lower than in October; 65% of the rock surfaces were bare. Beyond the canal, *Corallina* was the predominant algal species within the *Chondrus* denuded zone. As in earlier surveys the *Chondrus* denuded zone was more clearly delineated on the southern side of the transect line than on the north with most rock surfaces within 5 to 6 m of the transect line bare. Beyond this 6-m region, healthy *Chondrus* plants and other algal species occurred but coverage was less plush and diversity lower than in October. The mussel shell debris seen in October had disappeared. No *Laminaria* was present within the survey area.

The stunted zone was confined to the northwestern side of the denuded zone where it extended out to 19 m from the transect line at the 65-m mark. The area (183 m^2) of the stunted zone was 32% smaller than the northern portion had been in October. The *Chondrus* plants within the stunted zone were not only stunted in appearance but were sparsely distributed. South of the denuded zone a narrow band, at the most 2 m in width, of healthy but sparsely distributed *Chondrus*, occurred from the 33- to 73-m mark on the transect line.

4.0 CONCLUSIONS

4.1 FAUNAL STUDIES

- Species richness was lowest at Manomet Point and highest at Rocky Point in March 1991, whereas it was highest at the Effluent station and lowest at Manomet Point in October 1991. Species richness increased markedly at the Effluent station and to a lesser extent at Manomet Point between spring and fall. It decreased slightly at Rocky Point.

- Faunal densities were highest at the Effluent station, intermediate at Manomet Point, and lowest at Rocky Point in both the spring and the fall. Densities dropped drastically in October due to a sharp decline in the mussel populations.

- Dominant species were much more similar among stations in March than they were in October. The decline in mussel density allowed for occupation of the free space by groups of species that were different for each station. The community structure changed between March and October in that true dominants were no longer present in October. At the Effluent station, the diversity of the dominant fauna observed in the spring among the lower ranking species had disappeared in the fall when almost all abundant species were amphipods.

- Species diversity was lowest at the Effluent station and highest at Rocky Point in the spring, whereas it was highest at the Effluent station and lowest at Rocky Point in the fall. Although the Shannon-Wiener indices were relatively high in the fall, they were within range of H' measured in previous years, as well as the spring of 1991, when mussels were excluded.

- Similarity among stations showed clear seasonal differences. Additionally, the Effluent station showed some unusual similarity patterns throughout the year. In March, the Effluent station was very dissimilar from the reference stations, but all replicates of that station were very similar. In October, the replicates of the Effluent station split up into two groups that each showed high similarity with one of the reference stations. Analysis of the combined spring and fall data revealed that the Effluent station was dissimilar from all other 1991 stations regardless of the season.

4.2 ALGAL STUDIES

- Algal communities consisted mostly of red algae, including the dominant species *Chondrus crispus* and *Phyllophora* spp. Several species of green and brown algae were also collected.

- Community overlap between stations was higher between the Effluent station and both reference stations than between the two reference stations in the spring. However, in October, community overlap between the Effluent station and both Manomet Point and Rocky Point was lower than between the two reference stations, indicating that in the fall the Effluent station differed more from the reference stations than in the spring.

- Mean biomass of *Chondrus* increased at all stations between March and October. In March, *Chondrus* biomass was highest at Manomet Point and lowest at the Effluent station. In October, Manomet Point still ranked highest, whereas *Chondrus* biomass was lowest at Rocky Point. *Phyllophora* biomass, in March, was highest at Rocky Point and lowest at Manomet Point, whereas in October, the Effluent station had the greatest *Phyllophora* spp. biomass and Rocky Point the least. Between March and October, *Phyllophora* biomass increased at the Effluent station and Manomet Point but declined at Rocky Point. Biomass of the remaining benthic species was highest at Rocky Point and lowest at Manomet Point during both seasons. Epiphytic algal biomass, in March, was highest at Manomet Point and lowest at the Effluent station, whereas in October, it was highest at Rocky Point and lowest at Manomet Point. Total algal biomass increased from March to October at all three stations, by 43% at Rocky Point, 64% at Manomet Point, and 114% at the Effluent station.

4.3 QUALITATIVE TRANSECT SURVEYS

- The area of the *Chondrus* denuded and stunted zones increased slightly from December 1990 to March 1991, a period when the plant was in full operation. Between March and June the area of the denuded zone and total affected area decreased, reflecting the shutdown of the plant from May through July. The area of the denuded zone and total affected area continued to decrease through October but increased by the time of the December transect. The area of the denuded zone varied only moderately over the year; it was greatest in March (1320.5 m^2) and least in October (1080 m^2).

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APPENDIX A. LIST OF SPECIES IDENTIFIED AT THE EFFLUENT, MANOMET POINT, AND ROCKY POINT STATIONS IN 1990/1991 (*: PRESENT IN SPRING 1991)

Smaller Phyla

CNIDARIA
- **Haliclystus auricola* (present in spring 1991)

CNIDARIA

**Haliclystus auricola*
Metridium senile
*Anemone

PLATYHELMINTHES

*Acoel
*Turbellaria

NEMERTEA

**Cerebratulus lacteus*
*Nemertea
**Tetrastemma vittatum*

*SIPUNCULOIDEA

Annelida

*OLIGOCHAETA

POLYCHAETA

Ampharetidae
Asabellides oculata

Arenicolidae
Arenicola marina

Capitellidae
**Capitella capitata*
Mediomastus californiensis

Cirratulidae
Caulleriella bioculata
Chaetozone setosa
Chaetozone sp. 1
Cirratulus cirratus
**Dodecaceria corallii*
**Tharyx acutus*

Cossuridae
**Cossura longocirrata*

Dorvilleidae
**Meiodorvillea* sp. 1

Nephtyidae
**Nephtys caeca*
Nephtys longosetosa
Nephtys picta

Nereididae
Neanthes succinea
**Nereis pelagica*
Nereis zonata

Orbiniidae
**Naineris quadricuspida*

Paraonidae
**Aricidea catherinae*

Pectinariidae
Pectinaria granulata

Pholoidae
**Pholoe minuta*

Phyllodocidae
Eteone longa
**Eulalia viridis*
Eumida sanguinea
**Phyllodoce (Anaitides) maculata*

Polygordiidae
**Polygordius* sp. 1

Polynoidae
**Harmothoe extenuata*
**Harmothoe imbricata*
**Lepidonotus squamatus*

Sabellariidae
**Sabellaria vulgaris*

Sabellidae

**Fabricia sabella*
Potamilla neglecta
**Pseudopotamilla reniformis*

Sigalionidae

**Sthenelais boa*

Spionidae

Polydora cornuta
**Polydora giardi*
**Polydora socialis*
Polydora websteri
Prionospio steenstrupi
Spio filicornis
**Spio thulini*

Syllidae

**Autolytus alexandri*
**Autolytus cornutus*
Autolytus fasciatus
**Autolytus prismaticus*
Exogone hebes
**Syllides longocirrata*
Syllis (Typosyllis) cf. *hyalina*

Terebellidae

Nicolea venustula
**Nicolea zostericola*
Polycirrus eximius
**Polycirrus phosphoreus*

<u>Crustacea</u>

ISOPODA

Idoteidae

**Idotea phosphorea*
**Idotea balthica*

Janiridae

**Jaera marina*

Limnoridae

Limnoria lignorum

AMPHIPODA

Ampithoidae

**Ampithoe rubricata*

Aoridae

Unciola irrorata

Calliopidae

**Calliopius laeviusculus*

Corophiidae

**Corophium acutum*
**Corophium bonelli*
**Corophium insidiosum*
**Corophium tuberculatum*

Dexaminidae

**Dexamine thea*

Gammaridae

**Gamarellus angulosus*
Gammarus oceanicus
Marinogammarus stoerensis

Ischyroceridae

**Ischyrocerus anguipes*
**Jassa falcata*

Phoxocephalidae

**Phoxocephalus holbolli*

Pleustidae

**Pleusymtes glaber*

Pontogeneiidae

**Pontogeneia inermis*

Stenothoidae

**Metopella angusta*
**Proboloides holmesi*

CAPRELLIDEA

Caprellidae

**Caprella linearis*
**Caprella penantis*
**Caprella* nr. *septentrionalis*
Caprella unica

CUMACEA

Diastylis polita

Diastylis sculpta

DECAPODA

Cancer borealis

Cancer irroratus

Carcinus maenas

Crangon septemspinosa

Eualus pusiolus

Pagurus acadianus

Pagurus longicarpus

<u>Mollusca</u>

GASTROPODA

Acmaeidae

Acmaea testudinalis

Aeolidiidae

Aeolidia papillosa

Doto coronata

Calyptraeidae

Crepidula fornicata

Crepidula plana

Cerithiidae

Bittium alternatum

Columbellidae

Anachis translirata

Mitrella lunata

Coryphellidae

Coryphella rufibranchiata

Coryphella salmonacea

Cratenidae

Cratena pilata

Diaphanidae

Diaphana minuta

Facelinidae

Facelina bostoniensis

Lacunidae

Lacuna vincta

Lamellidorididae

Lamellidoris aspera

Littorinidae

Littorina littorea

Littorina saxatilis

Nassariidae

Nassarius trivittatus

Naticidae

Lunatia heros

Omalogyridae

Omalogyra atomus

Pyramidellidae

Odostomia dealbata

Odostomia gibbosa

Turbonilla elegantula

Rissoidae

Alvania pseudoareolata

Onoba aculea

Trochidae

Margarites helicinus

Margarites umbilicalis

BIVALVIA

Anomiidae

Anomia simplex

Anomia squamula

Cardiidae

Cerastoderma pinnulatum

Hiatellidae

Hiatella arctica

Hiatella striata

Lyonsiidae

Lyonsia hyalina

Mactridae

Spisula solidissima

Myidae

**Mya arenaria*

Mytilidae

Modiolus modiolus

**Mytilus edulis*

Petricolidae

**Petricola pholadiformis*

Tellinidae

**Macoma balthica*

Macoma tenta

**Tellina agilis*

Thraciidae

**Thracia septentrionalis*

Veneridae

Gemma gemma

**Mercenaria mercenaria*

POLYPLACOPHORA

Lepidochiton ruber

**Ischnochiton ruber*

<u>Echinodermata</u>

ASTEROIDEA

**Asterias forbesi*

Henricia sanguinolenta

ECHINOIDEA

**Strongylocentrotus droebachiensis*

OPHIUROIDEA

**Amphipholis squamata*

**Ophiopholis aculeata*

<u>Tunicata</u>

POLYCLINIDAE

Amaroucium constellatum

MOLGULIDAE

**Molgula* sp.

FINAL
SEMI-ANNUAL REPORT
Number 39
(Volume 2 of 2)

on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (IMPACT ON BENTHIC COMMUNITIES)

January-December 1991

to

BOSTON EDISON COMPANY
Regulatory Affairs Department
Licensing Division
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

From

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
89 Water Street
Woods Hole, MA 02543
(508) 540-7882

1 April 1992

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EXECUTIVE SUMMARY

This volume of the semiannual report summarizes the potential impacts caused by the PNPS on the benthic communities in the vicinity of the Pilgrim Nuclear Power Station. Field and laboratory studies are detailed in volume 1 of this report.

The cooling water that circulates through the plant is warmed and discharged through a canal into the nearshore waters of Cape Cod Bay. This discharged water includes three sources of potential impact on the benthic communities: 1) warming of ambient waters, 2) chemical discharges (mainly Cl_2), and 3) increased current velocities resulting in scouring of the bottom. Species composition and community structure may be changed to varying degrees depending upon climate and local oceanographic conditions. Scouring has a direct physical impact that actually removes benthic organisms and prevents recolonization. In its extreme, the bottom scouring results in rock surfaces that are completely denuded and devoid of macroscopic marine life. The following observations were recorded as part the 1991 Benthic Monitoring Program and compared with data from recent years.

Total number of species observed at the Effluent station were not related to plant operation, but may be related to habitat modification caused by changes in mussel populations. Total faunal density fluctuations are strongly influenced by mussel populations. Unusually high mussel populations were observed in the vicinity of the discharge canal and at the Effluent station in June 1990, but declined sharply in 1991. Mussels may have migrated to the site in response to higher temperatures from the thermal discharge or by the currents. Species diversities declined at all stations in 1990 and remained low in the spring 1991 samples. However, species diversity increased markedly in the October 1991 samples. PNPS did not appear to have any negative impact on species diversity in 1991 because the station with the highest diversity in October was the Effluent station.

Typically, the Effluent station exhibits a different clustering pattern in the similarity analysis during periods of plant operation. This pattern disappeared after the long 2-½ year shutdown and returned by the September 1990. This trend has continued in the 1991 samples. The Effluent station differs structurally from the two reference stations. In 1990, two species, one anemone (*Metridium senile*) and an amphipod (*Corophium tuberculatum*) were dominant at the Effluent station in the fall, but rare or absent elsewhere. In the spring 1991 a gastropod (*Turbonilla elegantula*) and a predatory polychaete (*Eulalia viridis*) were important at the Effluent station, but rare elsewhere. In the fall 1991 samples, two different groups of Effluent samples were defined in the cluster analysis. This difference appears to have been caused by the distributions of an amphipod (*Phoxocephalus holbolii*) and another group of five invertebrates represented by species group 1 (Table 9 in volume 1).

A composite assessment of all benthic community parameters including species richness, diversity, and density taken together with community composition indicates that subtle alterations in the Effluent station are probably the result of PNPS operation. In the October 1991 samples, the species richness and diversity values were actually highest at the Effluent station indicating an enhancement of benthic community parameters. The reasons for this enhancement are not clear, but depart from a more typical pattern where these parameters are generally reduced at the Effluent station.

In March 1991, the number of algal species shared (overlap) between the reference stations was lower than between the Effluent and reference stations, thus the community at the Effluent station was more similar to those at Manomet Point and Rocky Point stations than the two reference stations were to each other, only the fourth time this pattern has been seen since 1983. By October 1991, the (overlap) between the reference stations was higher than between the Effluent and reference stations, a return to the more typical situation. Thus, in 1991, the algal community at the Effluent station was more similar to those at the reference stations in March than in October.

Algal biomass did not follow the typical seasonal decline during the winter months. From September 1990 to March 1991 total algal biomass increased at the Effluent station and at Manomet Point and decreased only slightly at Rocky Point. Total algal biomass increased at all three stations during the summer of 1991, reaching levels not seen since the power plant resumed operation in March 1989. The warm-water alga, *Gracilaria tikvahiae*, was observed at the Effluent station during all four surveys; *Laminaria*, a cold-water species, was seen only at the reference stations.

The size of the denuded zone of the acute impact area was similar to that observed during previous times of full power plant operation. Area of the denuded zone is mainly influenced by circulating water pump operation and the slight decrease in affected area seen from the March to October surveys may be explained by the three-month outage in May, June, and July 1991. Typically, the denuded zone decreases in area during the spring, a time of abundant algal growth; this pattern was observed in 1991.

The algal community at the Effluent station was different from those at the Manomet Point and Rocky Point stations in 1990. The warm-water alga, *Gracilaria tikvahiae*, was observed at the Effluent station during the April, June and December surveys of 1991 (the absence of *Gracilaria* in September might be correlated with the low operating capacity of PNPS the preceding month).

INTRODUCTION

The Benthic Monitoring Program at the Pilgrim Nuclear Power Station (PNPS) began in 1972, and has continued to the present time with occasional modifications. The study was continued in 1991 under BECo Purchase order 68003, as required by NPDES Permit No. MA0003557 issued by the U.S. EPA and Massachusetts DWPC. The objectives of the program are to identify and assess any impact of the operation of PNPS on the nearshore marine epibenthic community. Benthic communities are excellent indicators of environmental perturbations because most of the organisms are sessile and are unable to migrate away from sources of disturbance. It is possible, therefore, to correlate changes in the benthic community, such as density or diversity, with changes in environmental conditions.

PNPS is a base-load, nuclear-powered electrical generating unit designed to produce 670 megawatts of electrical energy under full operational conditions. The station is cooled by water that is withdrawn from Cape Cod Bay. The cooling water is then returned to the Bay via a discharge canal that is designed to dissipate the heat from the water through rapid mixing and dilution. Two circulating pumps produce a combined water flow of approximately 20 m^3 per sec at full operational capacity. The cooling system at PNPS includes three sources of potential impact on the benthic community: 1) warming of ambient waters, 2) chemical discharges (mainly Cl_2), and, 3) increased current velocities resulting in scouring of the bottom. Increasing temperature may stress the community so that species composition and community structure change; the extent of such change depends upon season of the year and the influence of local oceanographic conditions. Increasing current directly affects the benthos by actually removing benthic organisms and preventing recolonization; intense bottom scouring may cause the rock surfaces to become bare and devoid of macroscopic marine life.

Operational conditions at the PNPS have provided an opportunity to assess long-term trends associated with the impact on the benthic community. Plant operations have included years of nearly full operation as well as times when there were complete shutdowns, sometimes for prolonged periods. The longest outage in the history of the plant began in April 1986 and continued until march 1989. During this period the benthic community associated with the effluent canal and nearby areas immediately offshore were subjected to reduced current velocity as the use of circulating pumps was restricted to one or none. In addition, the discharge water remained at ambient temperature. As a consequence, the benthic community normally affected by these effluent parameters recovered, so that by 1988 there was essentially no difference between the control stations and the areas near the discharge canal. Studies conducted since the power plant has returned to operation were designed to assess the impact of plant operation on a benthic environment that had returned to near ambient conditions.

Volume 2 of the Semi-Annual Report summarizes impact findings in relation to the Benthic Monitoring Program. It discusses overall trends in the data presented in Volume 1 and in previous reports in an effort to summarize the effects associated with PNPS operations on the benthic community. Volume 2 places particular emphasis on the effects of full plant operation following periods of prolonged and short plant shutdowns.

METHODS

The present design of the benthic monitoring program includes quantitative and qualitative approaches for determining the presence and extent of impacts associated with the PNPS. Specifications for methods and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by BECo as modified in 1981 (BECo, 1987). The quantitative studies were designed in order to compare benthic community parameters at three stations: 1) a surveillance station located approximately 120 m offshore from the mouth of the discharge canal (Effluent station), 2) a control or reference station located 0.25 nmi NW of the discharge canal (Rocky Point station), and 3) a reference station located 2 nmi SW of the discharge canal (Manomet Point station) (Figure 1). Algal and faunal community analyses performed on data collected from these stations are compared for spatial and temporal (seasonal) variability. Differences between the Effluent and reference stations are then examined for potential impacts associated with PNPS operation.

The Effluent station is located far enough offshore of the discharge canal that the most scouring effects present in the nearfield discharge area are moderated by dilution, wave action, and long-shore currents. The site, therefore, is believed to experience only subtle effects on community structure and species composition. In contrast, the nearfield discharge area itself is heavily impacted with considerable bottom scouring as evidenced by the algal denuded zone. In order to study this acutely impacted area, a qualitative diver transect study has been designed to map the effects on algal communities. Divers perform quarterly transect surveys to measure the extent of denudation and stunting of the algal flora in the nearfield discharge area. The focus of these studies is the commercially important red alga *Chondrus crispus* (Irish Moss), a species common to western Cape Cod Bay. Divers swim along a measured transect line in the nearfield discharge area. The divers note the boundaries of the denuded, stunted, and normal *Chondrus* zones. Variations in the size of these zones are recorded over time as a means of determining the area most severely affected by PNPS operations. Detailed descriptions of field methodologies are presented in the first volume of this report.

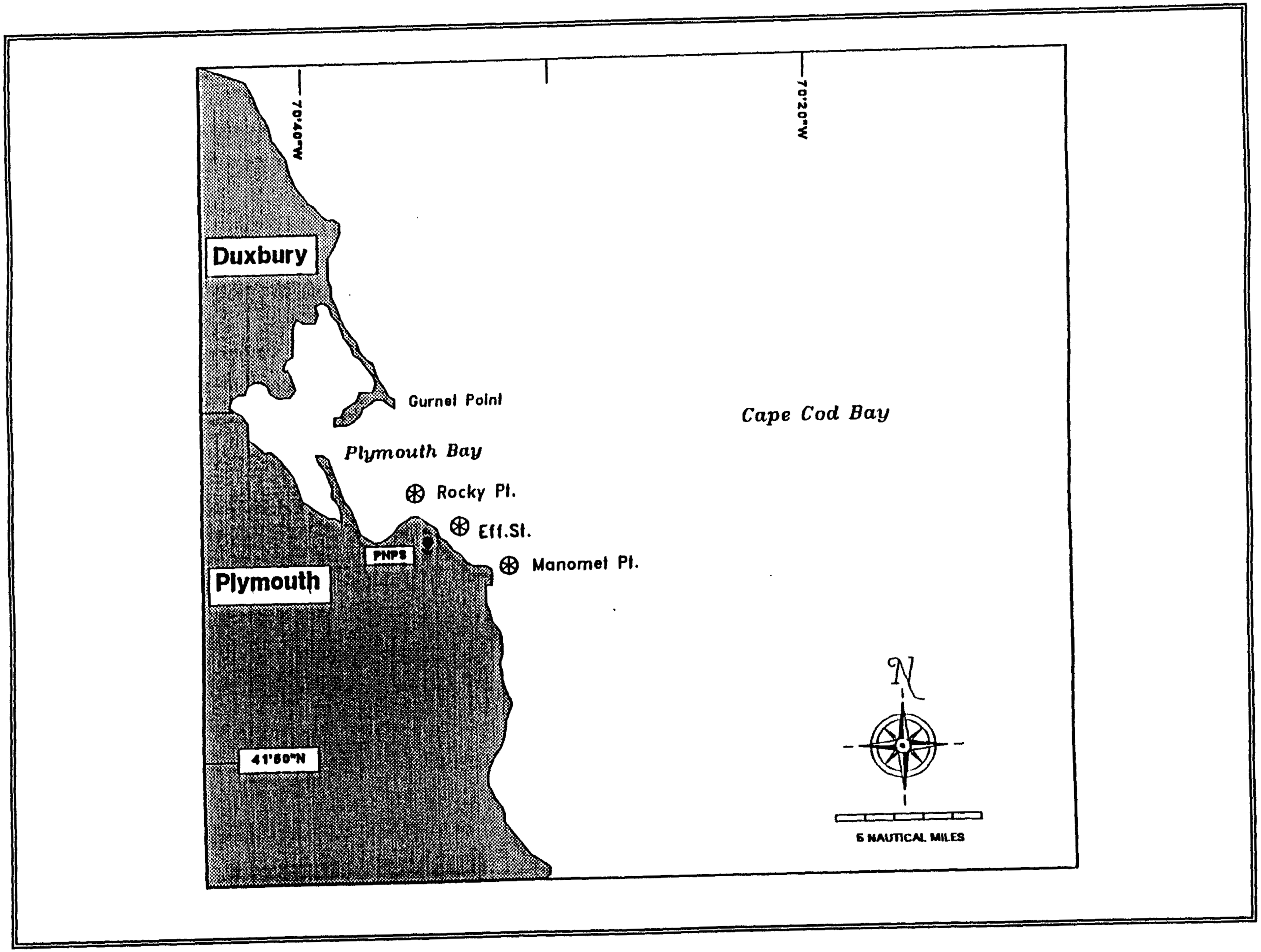

Figure 1. Location of Benthic Sampling Sites near Pilgrim Station.

BACKGROUND

PNPS operational conditions from 1983 through 1991 provide an opportunity to assess the degree of impact of the cooling water discharge on the benthic community and on the length of time it takes for this community to recover when the plant is shut down. Figure 2 depicts the annual maximum dependable capacity (MDC) factor and circulating water pump operation of PNPS since 1983. The MDC is a measure of reactor output that approximates thermal loading to the marine environment. A maximum MDC value of 100% represents the highest allowable change in ambient temperature for water discharge to Cape Cod Bay (18°C ΔT).

The cumulative capacity factor from 1973 to 1991 was 47.4%, but from 1983 to 1991 was only 38.0%. During the life of the plant, power output has varied greatly. The most productive years were 1978 (74.6%), 1979 (82.5%), 1983 (80.3%), 1985 (84.4%), and 1990 (72.3%). These very productive years frequently have been followed by low output years, with the most extensive period of no output lasting from April 1986 to March 1989. During times of plant shutdown or variable power outputs, only one of the two or none of the circulating seawater pumps may operate (Figure 2). During the shutdown that began in April 1986, one circulating pump operated much of the time, but there were extended periods when no pumps were in operation.

The longest power outage ended in March 1989 with the resumption of electrical generation and the operation of either one or both circulating pumps. The longest consecutive period of time that both pumps have been operating since March 1989 has been 12 months, from May 1990 through April 1991. Since then, the plant was shut down for three months, from May through July, for refueling and part of November.

QUANTITATIVE FAUNAL COMMUNITY STUDIES

Species Richness

The number of species collected at each station has been plotted over time as a measure of long-term species richness patterns (Figure 3). In terms of potential impact from the effluent discharged from PNPS, one obvious effect should be a reduction in numbers of species at the Effluent station during times of plant operation. At the same time, the numbers of species at the reference stations should remain consistently higher. Until 1987, this pattern was typically observed during periods when the level of operation of the plant was high. However, during the extended power outage, and especially from March 1987 to September 1988, the Effluent station exhibited lower numbers of species regardless. Following this period, the number of species at the Effluent station increased and all three stations were

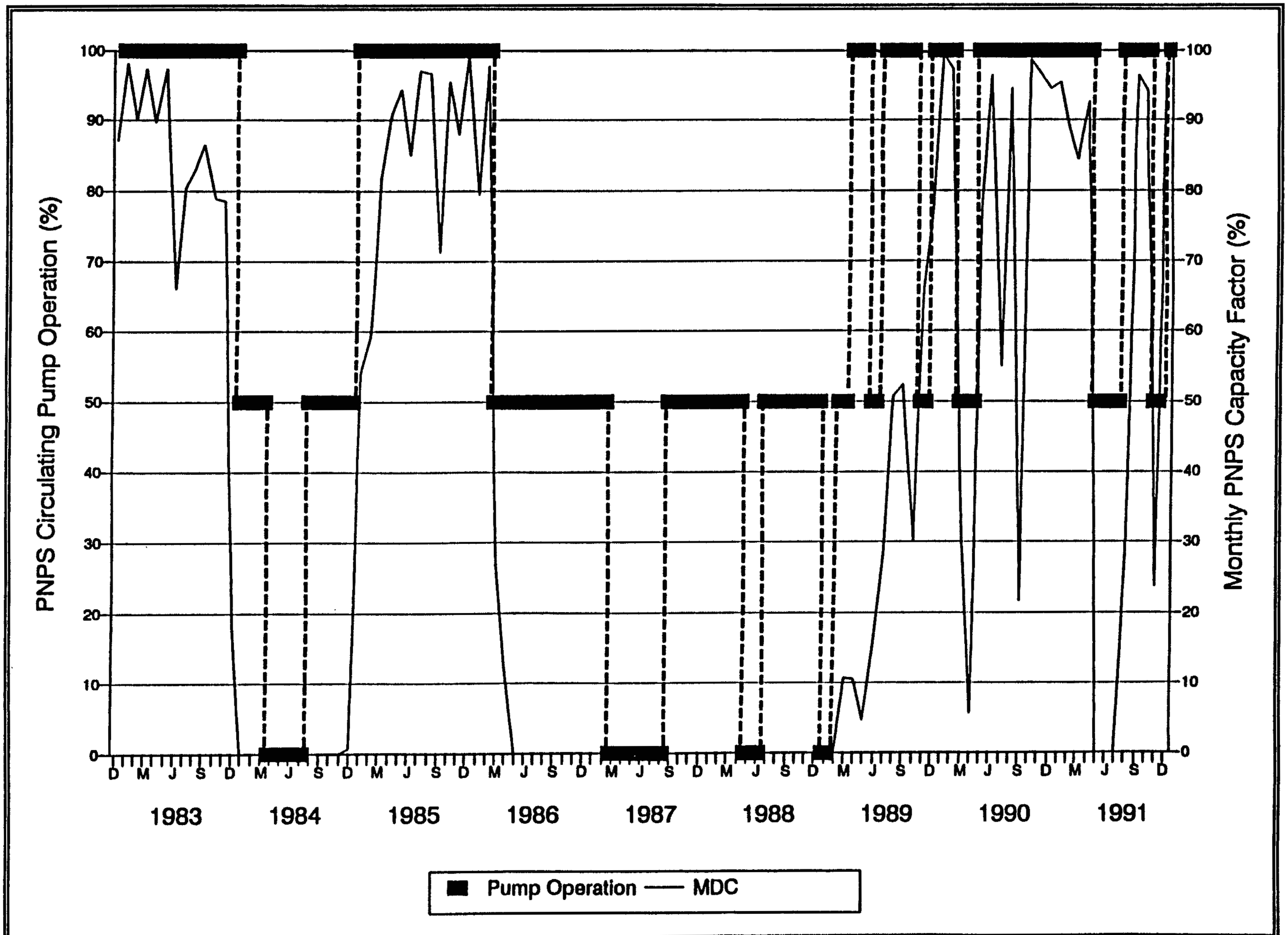

Figure 2. Monthly PNPS Capacity Factor (vertical lines) and Circulating Pump Activity (black bars at 100% = 2 pumps; at 50% = 1 pump; 0% = 0 pumps) Plotted for the Period 1983 Through 1991.

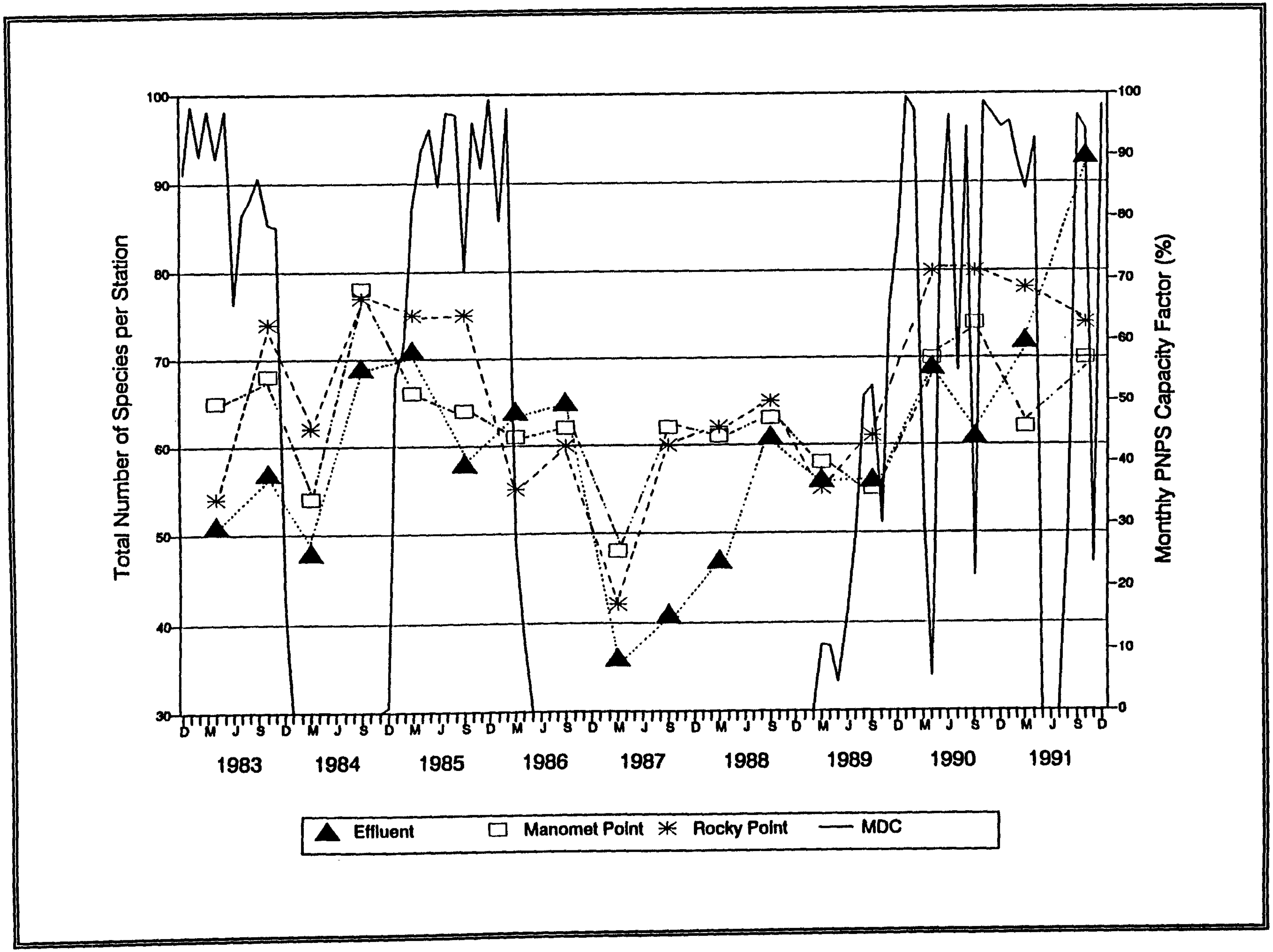

Figure 3. **Species Richness for the Period April 1983 Through October 1991 Plotted with Monthly PNPS Capacity Factor (MDC).**

essentially the same. By the fall of 1990, the number of species at the Effluent station had again been reduced in relation to the two reference stations. Beginning in 1990 the number of species present at the Effluent station increased to 72 in March and then to 93 in October. Both totals represent the highest species richness ever recorded at the Effluent station. In fact, the 93 species recorded from the Effluent station in October represents the most species ever recorded at any of the three stations. Among the control stations, the total number of species found at the Rocky Point station gradually declined from 80 species in both 1990 samplings to 73 in the October 1991 samples. At Manomet Point, the total number of species declined sharply from a high of 74 in September 1990 to 62 in March 1991, increasing to 70 in October.

These long-term results suggest that the numbers of species present at the Effluent station are not necessarily related to the operation of the PNPS. One very obvious correlation between the long-term trends in numbers of species is with the density of the blue mussel *Mytilus edulis*. During 1987, mussel populations were very low at all stations, then gradually increased to unusually high population levels in September 1988 (see below for qualitative observations on dense mussel populations in June 1990 and March 1991). This result correlates very well with the low counts of species at all stations that were observed in March 1987 and highs recorded in September 1988. In contrast, the major decline in mussel populations observed between the March and October 1991 collecting dates correlates very well with enhanced species richness and diversity at the Effluent station. Mussel density alone, however, does not provide a full explanation as for high species richness and diversity at the Effluent station because Manomet Point and Rocky Point exhibited similar declines in mussel densities, yet species richness and diversity did not increase as dramatically. Based upon species numbers, the Effluent station has historically had lower numbers of species than the references stations. This trend has not been consistent since the plant returned to full operation 1989. Thus, in terms of species richness, the thermal discharge does not appear to be adversely impacting the Effluent station.

Faunal Density

The total faunal densities from 1983 through 1991 are shown at all three stations (Figure 4). Total densities have fluctuated widely during this interval, largely because of periodic mass settlements of blue mussels. When mussels are removed from the density tabulations, total densities are typically much lower (Figure 5). There does not appear to be any seasonal correlation with total density at any station. Long-term variation in individual non-mussel species have not been investigated.

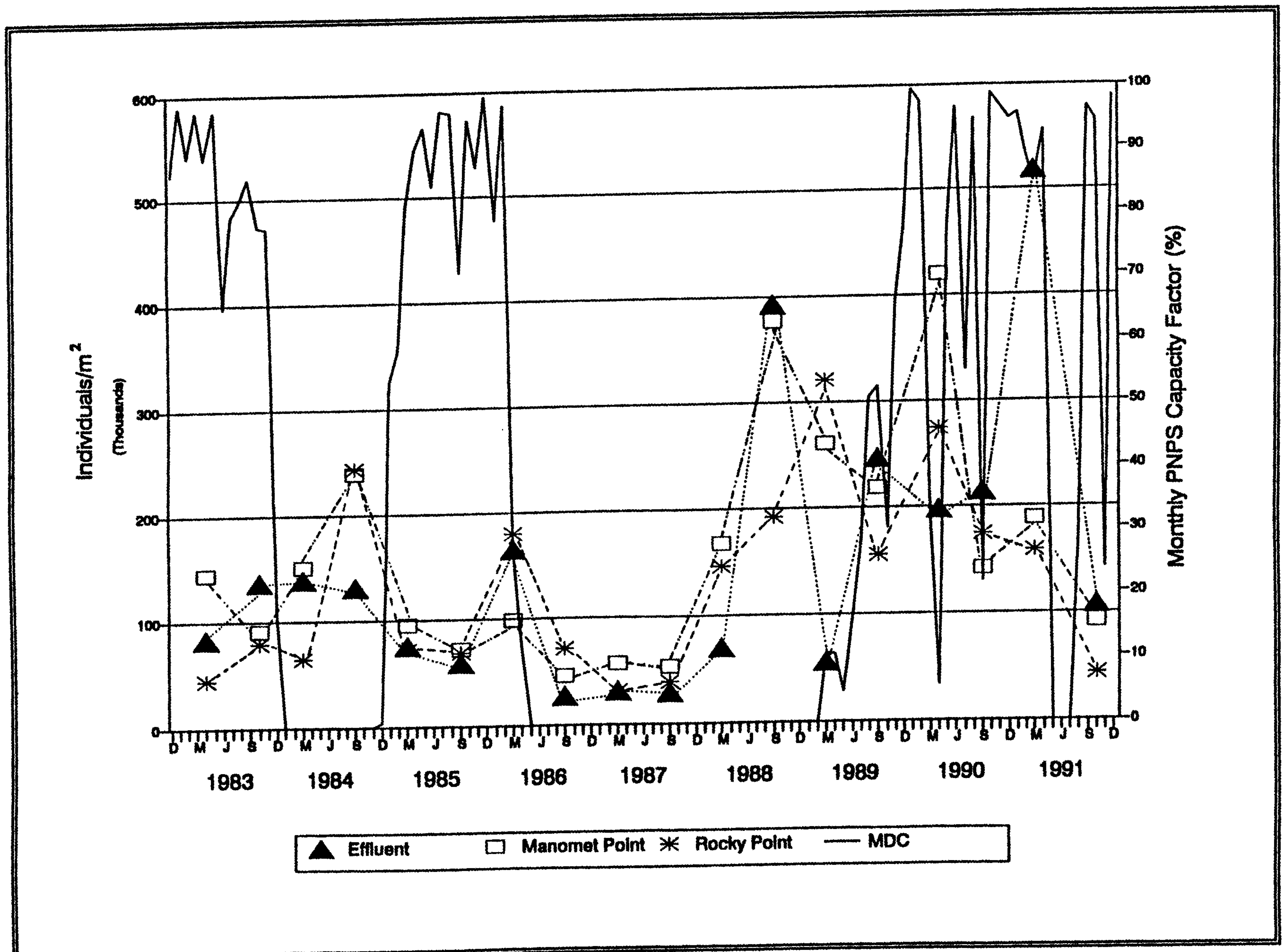

Figure 4. Total Faunal Densities (individuals per m²) for the Period April 1983 Through October 1991 Plotted with the Monthly PNPS Capacity Factor (MDC).

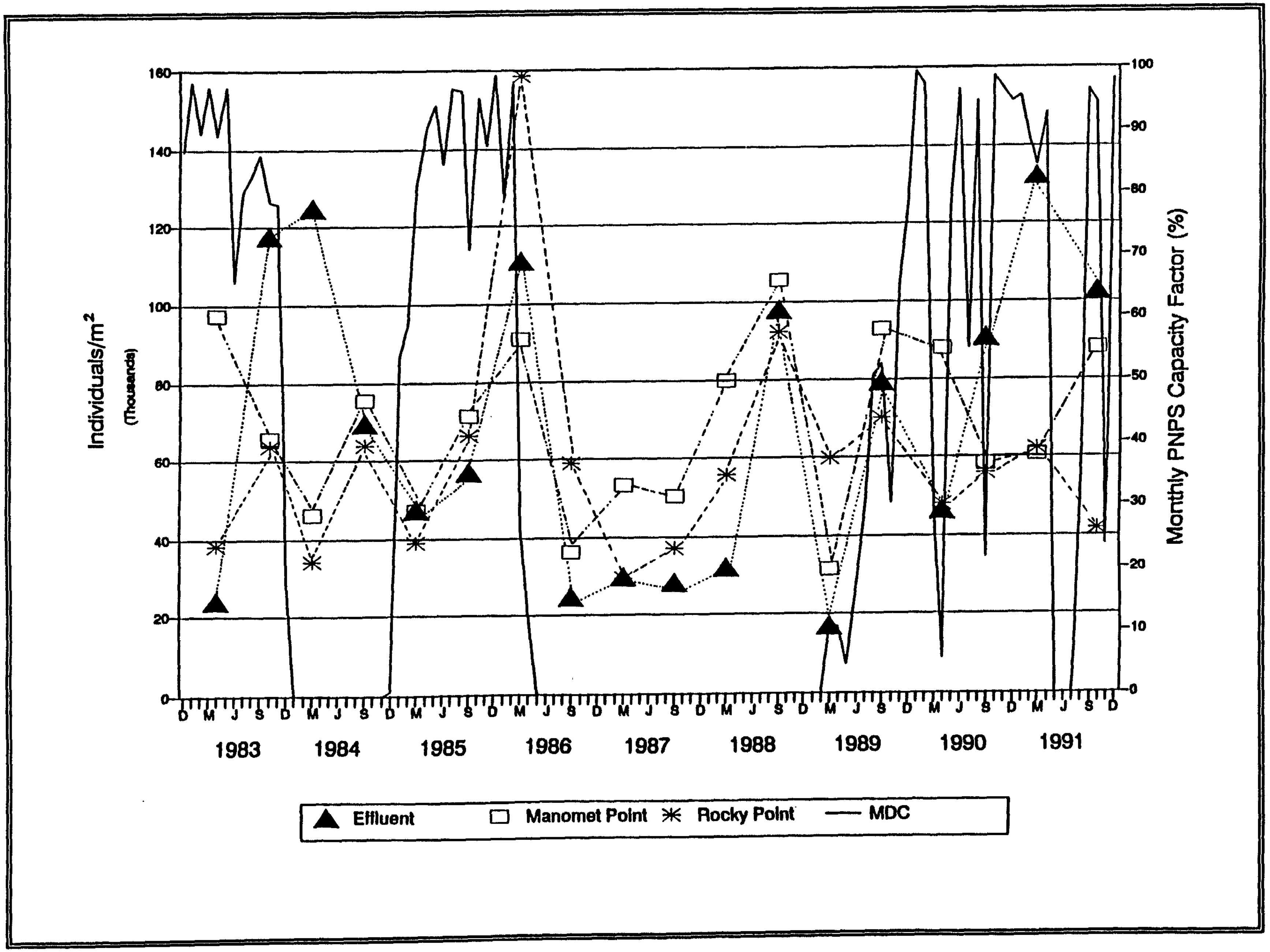

Figure 5. Total Faunal Densities, excluding *Mytilus edulis* (individuals per m²), for Period April 1983 Through October 1991 Plotted with Monthly PNPS Capacity Factor (MDC).

The biology of *Mytilus edulis* includes initial larval settlement on filamentous red algae followed, after a period of growth and development, by migration to sites of secondary attachment. The migration of these "plantigrade" juveniles is probably more important than the initial settlement and may explain the unusually dense populations that were observed in the effluent canal area in June 1990 as part of the qualitative transect surveys. The mussels were mostly small, but were observed to be so thick that the algae were completely buried by the masses of mussels. This population had been considerably reduced in September and was completely gone in December. This reduction in mussel population was probably caused by starfish predation, many individuals of which were observed to be associated with the mussels in June.

In 1991, densities of *Mytilus edulis* remained relatively low at both Manomet Point and Rocky Point in March, while they increased at the Effluent station to one of the highest levels ever recorded. In October 1991, however, densities dropped to their lowest levels since 1986 and 1987, resulting in very low total faunal densities at all three stations (Figure 4).

Historically, mussel populations at the Effluent station have been both higher and lower than the reference stations at Manomet Point and Rocky Point. No consistent pattern can be discerned from the data. It is likely that both the presence and absence of mussels strongly influence the density, richness, and diversity of the benthic communities at these stations. Populations of larger mussels would create habitat by providing space within the byssal threads, while their absence would provide space for other colonial organisms to settle and grow and likewise provide additional habitat. Mass settlements of juveniles probably reduce species richness because habitat space for settlement and other activities such as feeding would be decreased.

Species Diversity

Species diversity is a measure of the relationship between the number of species (richness) and their abundance in the community. Species diversity has been calculated in this program both with mussels included and excluded because their high numbers sometimes obscure potential patterns. Two measures of diversity have been presented in the BECo reports. The first is the Shannon-Wiener (H') index, with its associated evenness (Pielou's J'), and the second is Hurlbert's rarefaction (See volume 1 for details).

Long-term summaries of H' values are provided in Figure 6. Typically, a seasonal pattern is evident, where low diversity values in the spring are followed by higher values in the fall. This pattern was observed, with few exceptions, more or less regularly from 1983 through 1989. In the 1990

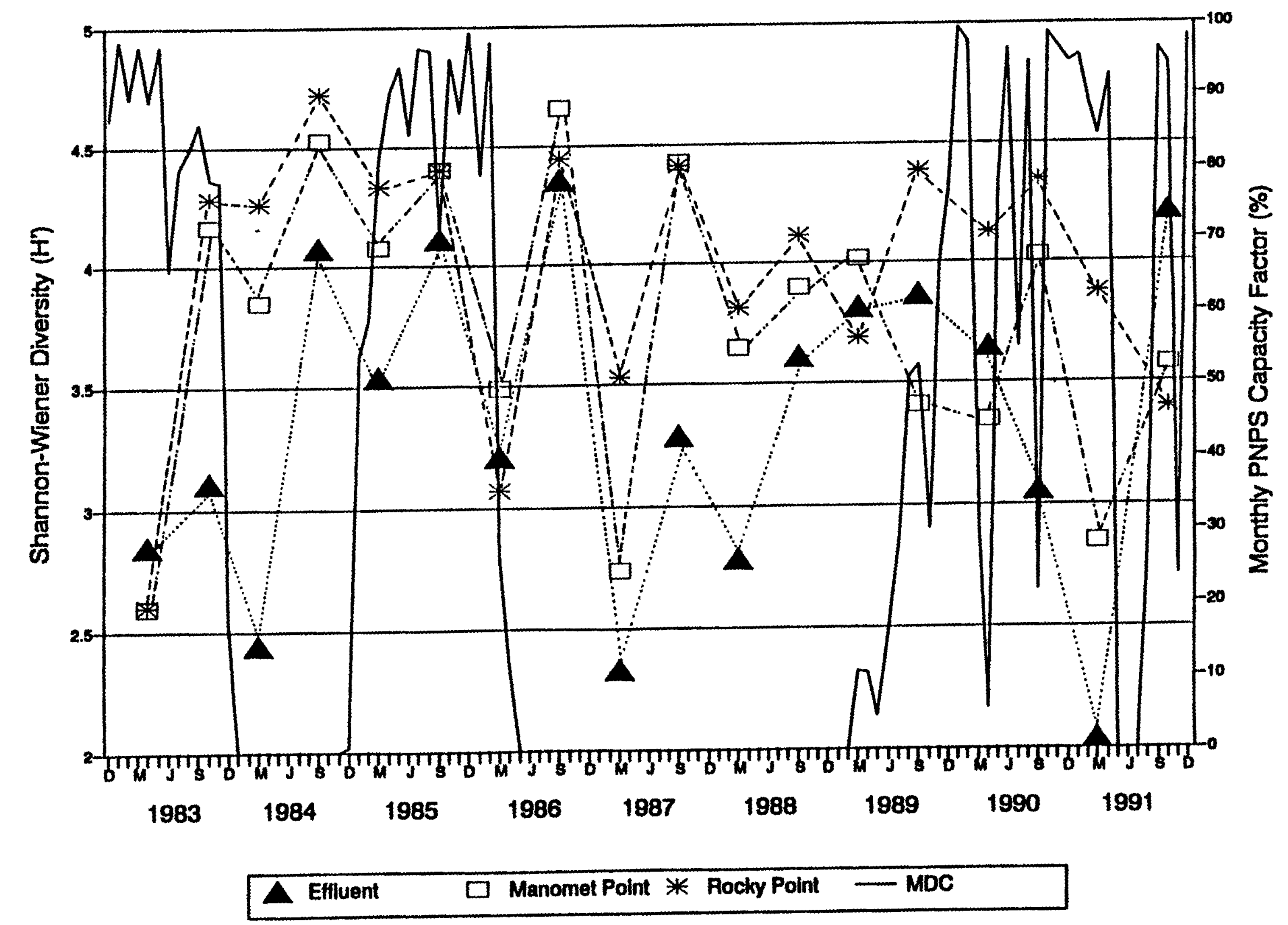

Figure 6. Shannon-Wiener Diversity (H') Index for Data Excluding *Mytilus edulis* for the Period April 1983 Through October 1991 Plotted with the Monthly PNPS Capacity Factor (MDC).

samples, however, species diversity increased at both Manomet Point and Rocky Point between spring and fall, but decreased at the Effluent station. This latter result corresponded with a decrease in the total number of species at the same station (BECo, 1991). In 1991, species diversities dropped at all three stations in March. Diversities were very low at the Effluent station. In October, however, *H'* increased to 4.3 at the Effluent station, the second highest value ever recorded at the station (Fig. 6). This was also the first time that the Effluent station was observed to have higher diversities than either of the control stations.

Similarity Among Stations

Cluster analysis was used to compare the community structure at each of the stations between seasons for 1991 (Figure 7). Historically, the benthic assemblage at the Effluent station has differed structurally from the Manomet Point and Rocky Point stations (e.g., BECo, 1985, 1986, 1987, 1988, 1989). This difference has been evident in the similarity or cluster analysis. These results have suggested that a subtle farfield impact of the PNPS discharge affects the overall faunal composition at the Effluent station. As evidence for this long-term observation, the Effluent station became indistinguishable from the controls at the end of the 2-½ year shutdown period in (BECo, 1990). The structure of the community did not immediately change following the shutdown; it took nearly two years before the stations became similar enough in the analysis for the replicates from the controls to mix with the Effluent station (BECo, 1990). There is thus a lag effect evident in the impact of the PNPS operation on the benthic community structure. A plant shutdown does not produce an immediate change in clustering patterns.

In the spring of 1991, the similarity analysis indicated that the Effluent samples joined the reference stations at a very low level of similarity, indicating that the faunal assemblage was considerably different (Figure 7). This difference was attributed to the presence of two species groups that were abundant at the Effluent station, but rare elsewhere (See volume 1 of this report). The fall 1991 samples were unusual in that the samples from the Effluent station were divided into two groups that joined with different clusters of reference station samples (Figure 7). The basis for these clustering pattern can be attributed to the variable distribution of individual species such as the amphipod *Phoxocephalus holbolli*.

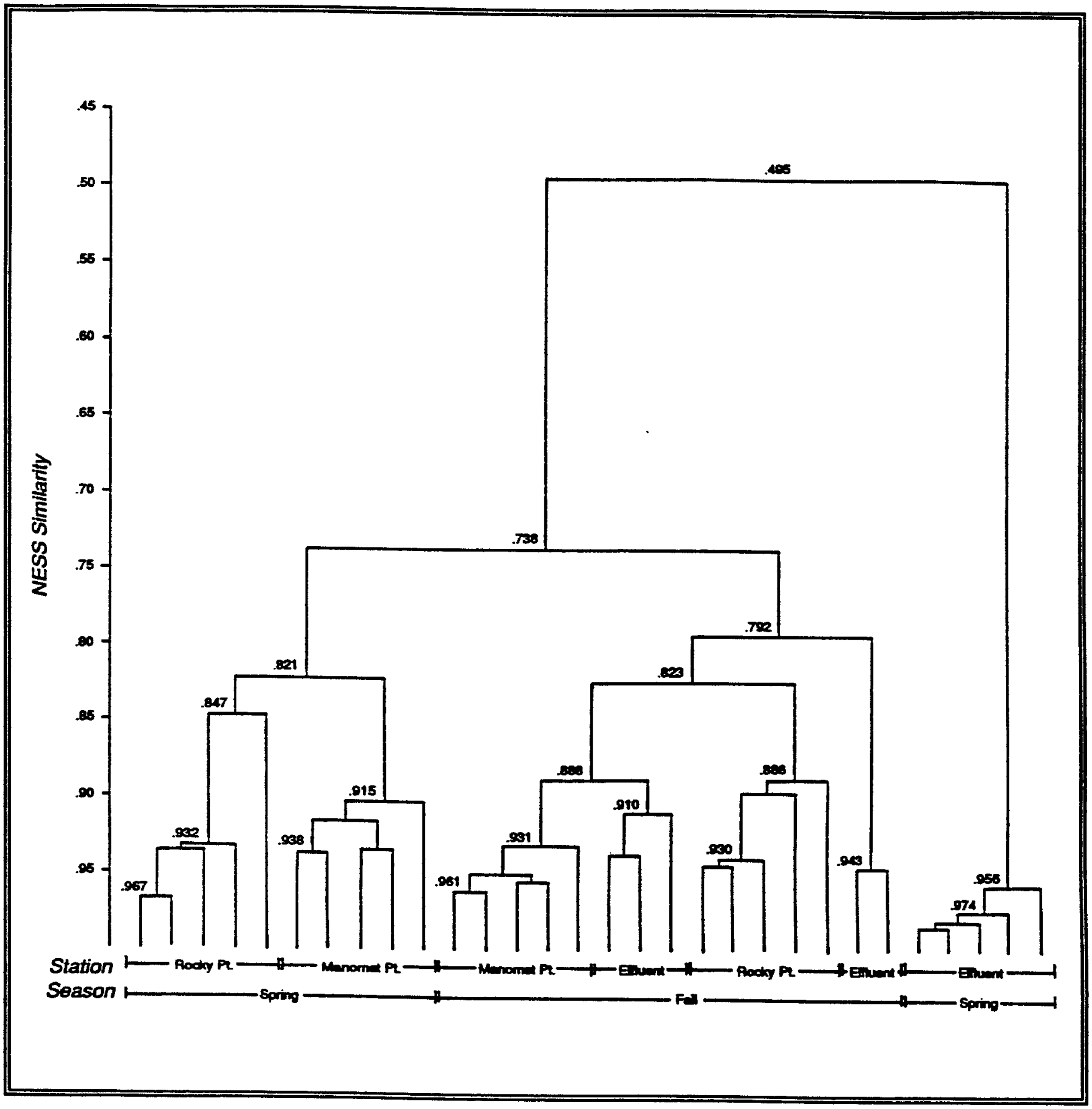

Figure 7. Similarity Analysis Based on NESS and Group Average Sorting, Spring and Fall 1991 Data Combined.

The community analysis has consistently indicated that during normal periods of PNPS operation, the Effluent station differs from the reference stations at Manomet Point and Rocky Point. These differences disappeared in late 1989 after the plant had been off-line for 2-½ years. The community patterns are now reestablished. The differences in the faunal assemblages at the Effluent station are unusual in 1991 because the fall samples exhibit elevated benthic community parameters (diversity, richness, numbers of species) over the reference stations. When these data are taken into account, the effect of the PNPS on the benthic community in Fall 1991 is more one of enhancement than one of diminishment. One possible explanation for the increase in community parameters at the Effluent station is that the brief plant shutdown in 1991 (May-July) occurred during the maximal time of larval availability leading to successful settlement at a site of reduced species richness.

Discussion—Faunal Studies

Results of the 1990 and 1991 quantitative benthic faunal studies indicate that the Effluent station differs structurally from the two reference stations. These differences include traditional benthic community parameters, such as species diversity and density, as well as overall community composition as revealed by cluster analysis. Further inspection of the 1990 and 1991 data indicated that in September 1990, two species (*Metridium senile* and *Corophium tuberculatum*) had become dominant at the Effluent station that were either not important or were entirely absent at the reference stations. In 1991, other groups of species were apparent that provided the Effluent station with a different overall faunal assemblage from the controls. In the spring 1991 samples a gastropod (*Turbonilla elegantula*), and a predatory polychaete (*Eulalia viridis*) were important at the Effluent station, but rare elsewhere. In the fall 1991 samples, two different groups of species were defined in the cluster analysis, including an amphipod (*Phoxocephalus holbolli*) and another group of five invertebrates.

The results of the 1991 benthic community studies supported the conclusions reached in the 1990 report (BECo, 1991) that the benthic communities at the Effluent station differed from those of the reference stations. Near the end of the long 2-½ year power outage at the plant, the Effluent station and reference stations became essentially indistinguishable from one another (BECo, 1990). After a full year of renewed plant operation, some changes began to emerge in the structure of benthic communities near the discharge canal (BECo, 1991). No one single benthic parameter was cited as evidence of PNPS having an impact on benthic communities, but when all were taken together, a cumulative impact was evident. Those trends observed in the 1990 samples are again evident in 1991. An interesting twist, however, is that the benthic community at the Effluent station appears to have enhanced species richness and diversity that are higher than either Manomet Point and Rocky Point instead of being lower.

Faunal communities that are associated with thermal discharges and under some stress, are believed to be characterized by low densities, few species, and elevated diversities (Logan and Maurer, 1975). Species that dominate in such an environment tend to be opportunists or pioneers. At the Pilgrim Station, benthic communities located offshore of the discharge canal do not appear to be subjected to extreme stress, although low levels of potential stress were apparently present in the September 1990 samples, as evidenced by depressed density, diversity, and richness (BECo, 1991). In the October 1991 samples, however, this trend reversed, with an enhancement of the community. The data on faunal density suggest that mussel density can subtly impact other community parameters by influencing which species are able to settle or become associated with the different stations.

The impact of PNPS operation on benthic communities in the farfield is thus difficult to predict. The pattern of lower benthic parameters at the Effluent station and higher ones at the reference stations was reversed in the 1991 samples.

QUANTITATIVE ALGAL COMMUNITY STUDIES

Algal Community Descriptions

The algal community at the Effluent station is dominated by the red macroalgae, *Chondrus crispus* and *Phyllophora* spp. These species are also dominant at the Manomet Point and Rocky Point stations. Less abundant but nonetheless important algal species are those that indicate en effect upon the community by the thermal effluent of PNPS. These important species include *Gracilaria tikvahiae*, a warm-water species (BECO, 1982), and *Laminaria* spp., a typical cold-water alga, prevalent along the northeast coast of the United States. *Gracilaria tikvahiae* does not occur at the reference stations but occurs regularly at the Effluent station during normal operational years of PNPS. *Gracilaria tikvahiae* abundance decreased drastically during 1986 and the species was entirely absent from the denuded zone during 1987, the second year of the nearly three year power outage. Conversely, *Laminaria* spp. was present within the area that had formerly been the acute impact zone during all four observation periods in 1987, 1988, and in March and June of 1989. The disappearance of *Laminaria* spp. by September 1989 and the reappearance of *Gracilaria tikvahiae* coincided with the return of PNPS to operational status. During 1991 *Gracilaria* was observed by the divers within the discharge canal area during all four seasons. *Laminaria* spp. was only observed at the reference stations.

Algal Community Overlap

Table 1 presents algal community overlap values (i.e., the percentage of shared species) between pairs of stations from 1983 through 1991. In general, the Manomet Point and Rocky Point stations have been more similar to each other (higher percentage overlap) than either have been to the Effluent station. One exception to this pattern occurred in the fall of 1985 while the plant was in full operation; three exceptions to this pattern occurred in the spring, once during the extended shutdown period in 1988, and twice while the plant was in full operation, in 1983 and this past year in March 1991. The exceptions to the general pattern appear not to be correlated with power plant operation and may depend upon meteorological and oceanographic variability in Cape Cod Bay (BECO, 1989) for those years and seasons. In addition, the nearly three-year power shutdown of PNPS from April 1986 until March 1989 did not cause any marked changes in the dominant algal species composition, indicating that PNPS operations have had little effect on species composition.

As in most previous years, the overlap values for the various station pairs in 1991 (Manomet Point vs. Rocky Point, Manomet Point vs. Effluent, and Rocky Point vs. Effluent) were not very different; the March and October overlap values had ranges of 7.0% and 7.2%, respectively. The small range in overlap values seen for most sampling periods indicates a relatively homogeneous algal species distribution among all three stations. In 1991, species overlap between the reference stations was typical of levels observed prior to 1990 when unusually high overlap was seen.

Algal Biomass

The March 1991 samples were similar to the March 1990 samples in that algal biomass failed to follow the typical seasonal decline during the winter months. Rather, at the Effluent station and at Manomet Point the mean values for total algal biomass increased from September 1990 to March 1991 (Figure 8), and the biomass at Rocky Point only decreased very slightly. During the summer of 1991, total algal biomass increased at all three stations, reaching levels not seen since the power plant resumed operation in March 1989. This may be related to the three-month shutdown of the plant from May through July. The summer increase in biomass at the Effluent station and Manomet Point was due to an increase in biomass of the red algae *Chondrus crispus* and *Phyllophora* spp. In addition, at the Effluent station the biomass of the epiphytic species associated with the red algae increased dramatically (> 800%). At Rocky Point, however, the increase in total biomass resulted solely from biomass increase of the remaining benthic species and the epiphytes; biomass of both species of red algae actually declined.

Table 1. Algal Community Overlap in Percent Between Station Pairs for the Period 1983-1991.

Year	Season	Overlap (%)		
		MP vs. RP	MP vs. EFF	RP vs. EFF
1983	Spring	81.0	85.2	81.0
	Fall	77.8	67.9	73.0
1984	Spring	76.0	68.0	70.4
	Fall	84.0	73.1	71.0
1985	Spring	88.0	77.0	75.0
	Fall	65.5	73.1	88.9
1986	Spring	90.9	76.9	80.8
	Fall	84.0	70.4	77.8
1987	Spring	77.2	66.7	70.8
	Fall	80.0	80.0	76.0
1988	Spring	88.9	81.5	82.5
	Fall	82.8	89.7	85.7
1989	Spring	81.5	76.9	80.0
	Fall	87.0	85.2	74.1
1990	Spring	96.3	88.9	92.6
	Fall	96.0	80.8	84.6
1991	Spring	81.5	88.5	84.6
	Fall	90.5	83.3	83.3

Discussion—Algal Studies

By the end of 1991, PNPS had been in operation for nearly three years, except for a three-month hiatus from May through July in 1991 and a few other brief interruptions. Measures of similarity between station pairs (Jaccard's coefficient of community) show that in the spring of 1991 the Effluent station was more similar to the reference stations than the reference stations were to each other, a situation seen in only four sampling periods since 1983. By October 1991, the reference stations were again more similar to each other than they were to the Effluent station, the more typical condition. This change, with the reference stations becoming more similar to each other and less similar to the Effluent station in the fall is caused, in part, by the number of species occurring at the reference stations in the fall being lower than in any of the other 1991 samples. Of 27 species observed in the spring, 24 species were present at the Effluent station and Rocky Point and 25 species occurred at Manomet Point. However, in the fall, of 24 species recorded, all 24 species were present at the Effluent and only 20 species at each of the reference stations.

The effect of power plant operation upon the algal community has been confined primarily to changes in species composition rather than biomass. This pattern was repeated in the 1991 samples. Biomass values for the major algal categories failed to show any differences among stations for either season that would indicate a significant effect of PNPS at the Effluent station (Figures 8-10). The impact of PNPS on the algal communities of the Effluent station is reflected in the presence or absence of several less dominant species, probably because of differences in ecological requirements of the different species. For example, the warm-water species *Gracilaria tikvahiae* is found only at the effluent station during times of thermal discharge and the cold-water species *Laminaria* spp. is found only at the reference stations.

QUALITATIVE TRANSECT SURVEYS

Results of the qualitative transect surveys from 1983 through 1991 are presented in Figure 11. The total acute impact area (denuded, stunted, and including sparse in June and December) is plotted with the area of the denuded zone only and the monthly PNPS capacity factor (MDC). The difference between the denuded and total acute impact zones represents the stunted zone (and included a sparse zone in June and December 1991). A lag-time in recovery response by the acute impact zone to the 1984 PNPS power outage was reported in Semi-Annual Report No. 27 (BECO, 1986). Evidence of this slow recovery included a decrease in the area of the total acute impact zone that began in mid-1984 (5 months after the cessation of power plant operations) and continued through mid-1985. Between December 1984 and

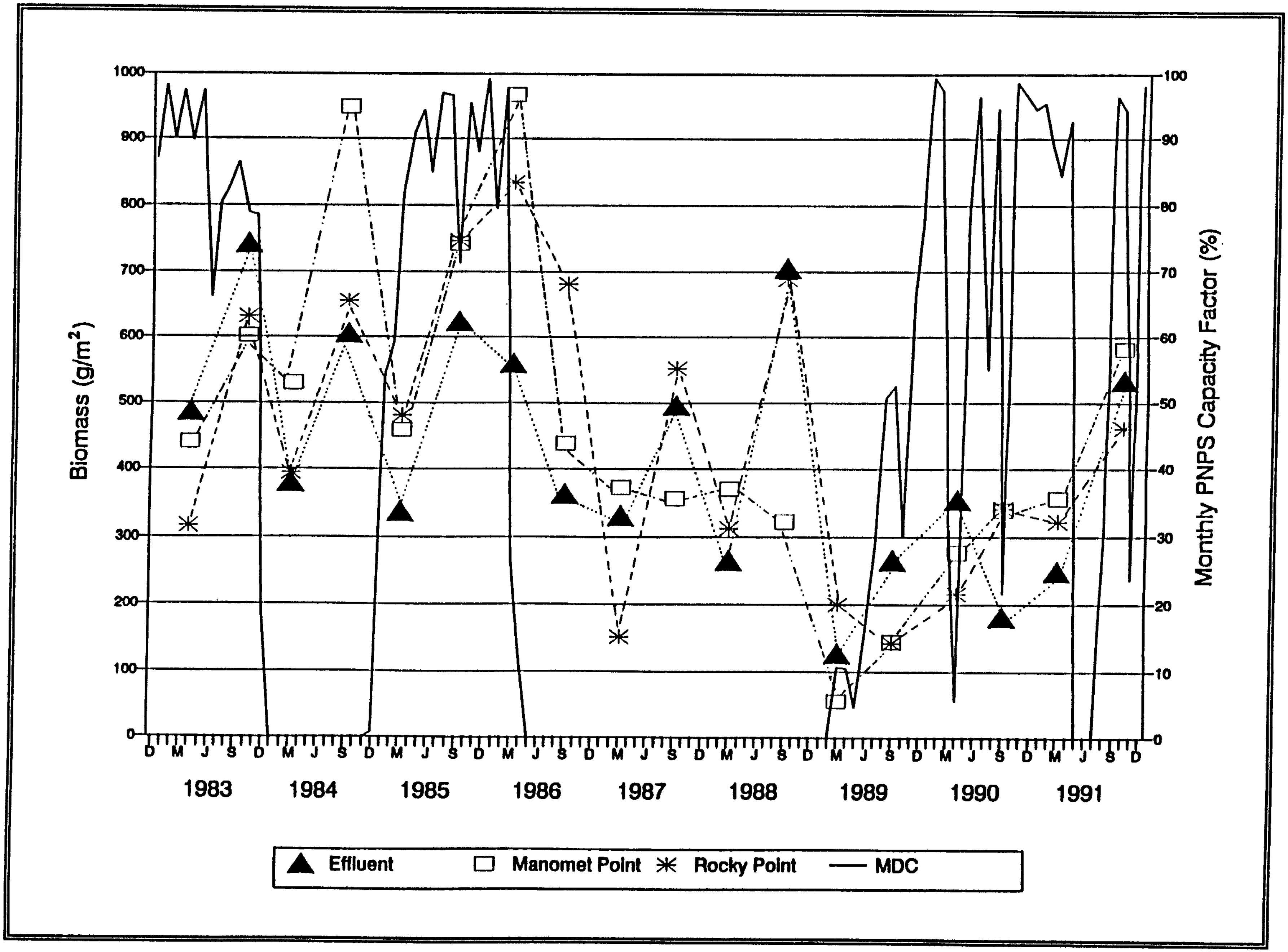

Figure 8. Seasonal Fluctuations in Total Mean Algal Biomass at the Manomet Point, Rocky Point, and Effluent Stations During Spring and Fall Sampling Periods for the Collections Between April 1983 and October 1991 Plotted with the Monthly PNPS Capacity Factor (MDC).

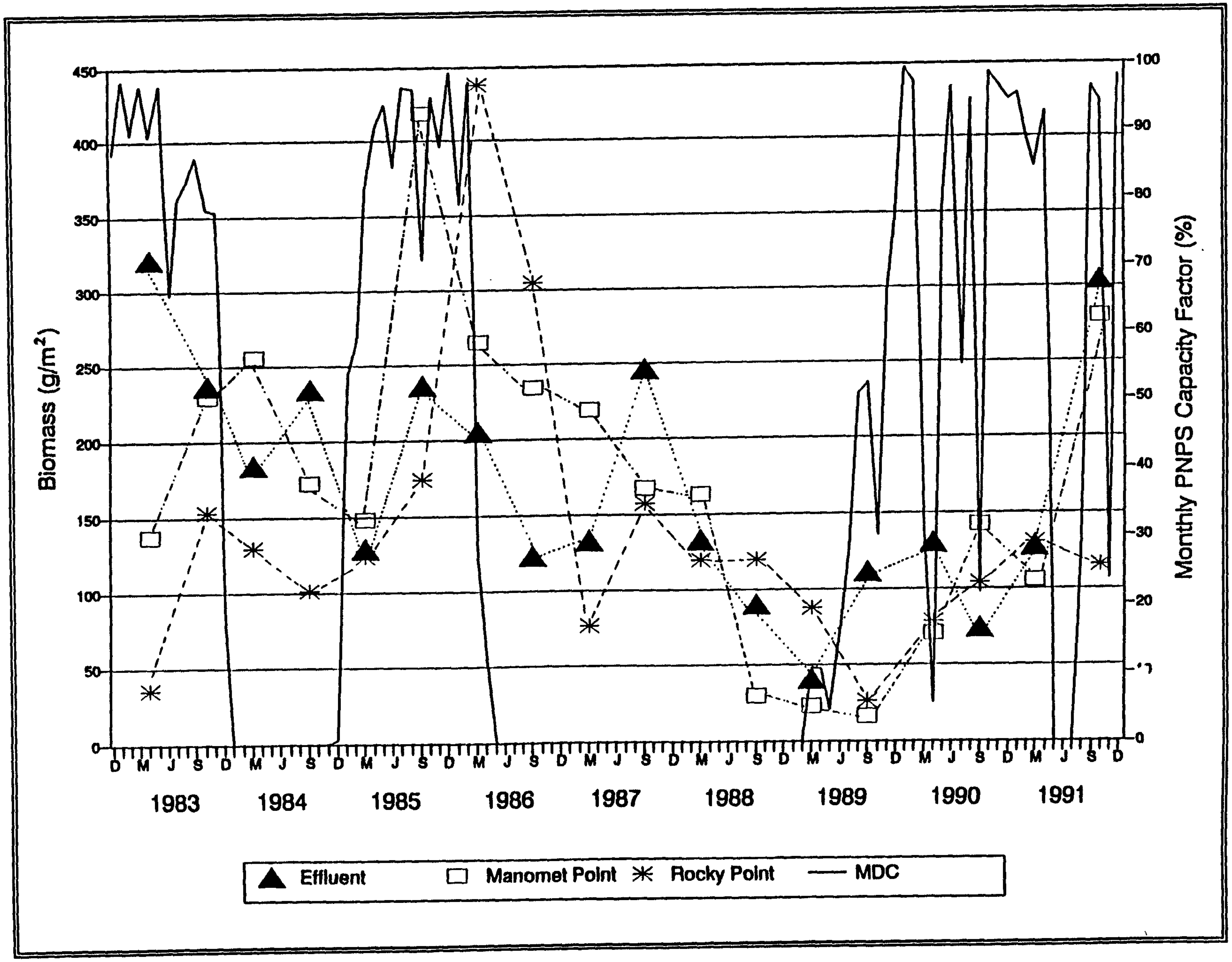

Figure 9. Seasonal Fluctuations in Total Mean *Phyllophora* Biomass at the Manomet Point, Rocky Point, and Effluent Stations During Spring and Fall Sampling Periods for the Collections Between April 1983 and October 1991 Plotted with the Monthly PNPS Capacity Factor (MDC).

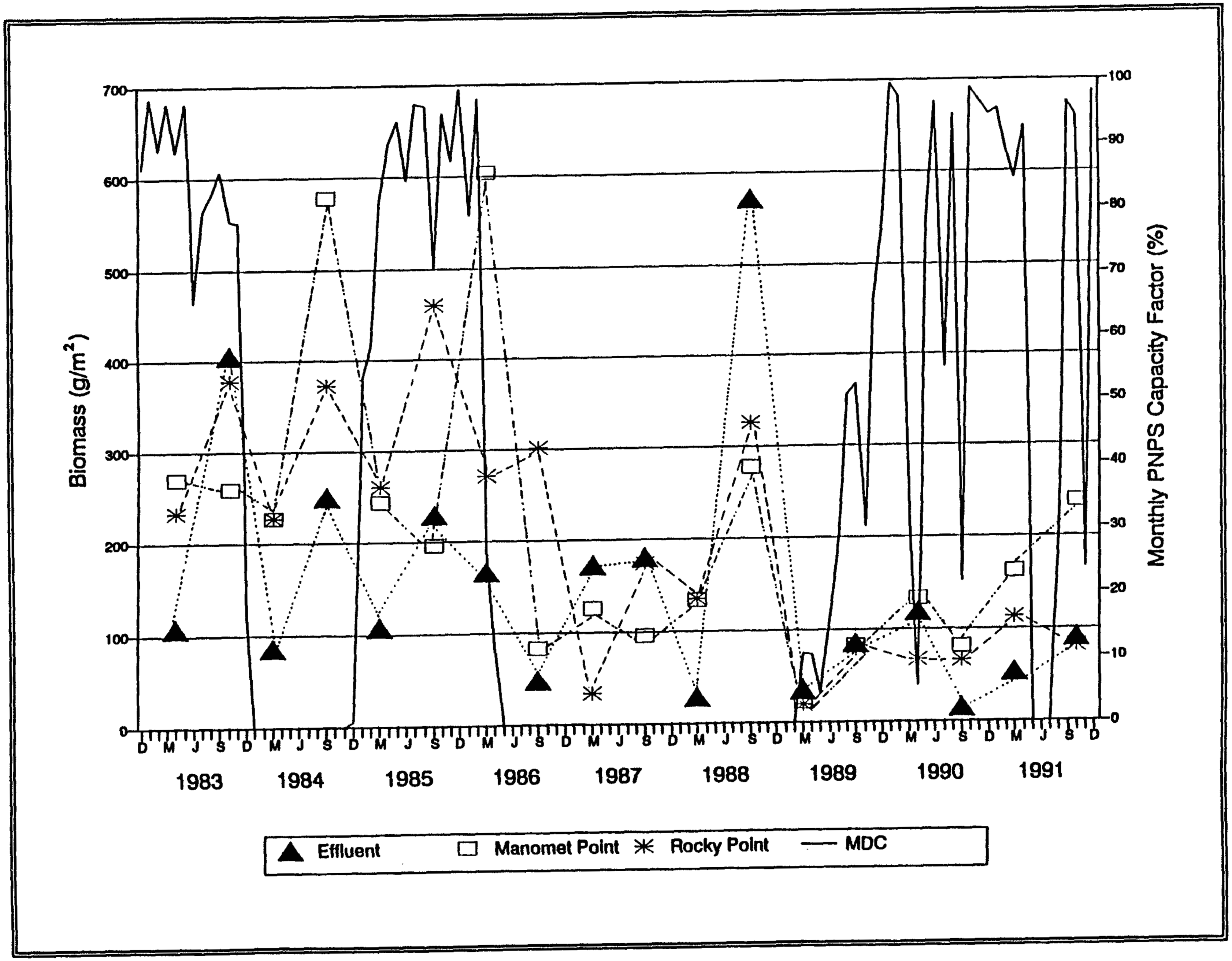

Figure 10. Seasonal Fluctuations in Total Mean *Chondrus* Biomass at the Manomet Point, Rocky Point, and Effluent Stations During Spring and Fall Sampling Periods for the Collections Between April 1983 and October 1991 Plotted with the Monthly PNPS Capacity Factor (MDC).

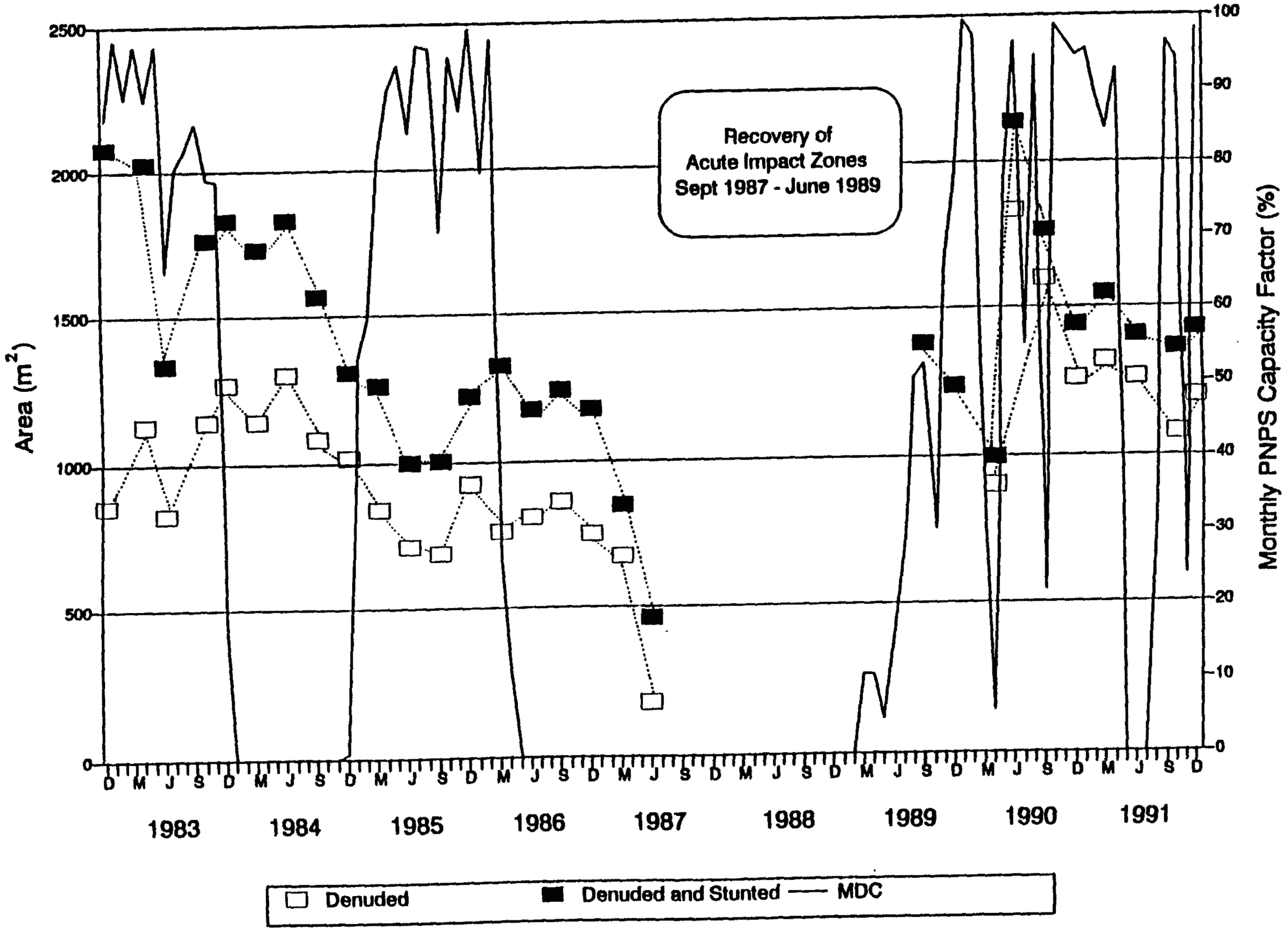

Figure 11. Area of the Denuded and Stunted Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC). No area measurements were made in September and December 1987, and March and June 1989 because of lack of definitive demarcations of denuded and stunted zones.

December 1985, the total impacted area (denuded and stunted zones combined) was the smallest recorded between 1983 and 1986, indicating a delay in recovery of this area in response to the absence of thermal discharge in 1984. This phenomenon reversed itself under normal PNPS operating conditions, so that only 6 to 9 months after the resumption of thermal effluent discharge the size of the acute impact zone began to increase between September and December 1985. These results confirmed a delay period of about 6-9 months between the causal factor (cessation or resumption of thermal effluent discharge) and associated response (decrease or increase of the acute impact zone size).

In 1987, increased recolonization of the denuded and stunted zones by *Chondrus crispus* made zone boundaries difficult to distinguish (no areal differences could be discerned from September 1987 through June 1989). As in summer 1984, the considerable decrease of the denuded area of the acute impact zone from December 1986 to June 1987 was mostly the result of the shutdown of the circulating water pumps from late march to early September (BECO, 1988). Apparently, water current scouring is a greater stress to algal colonization than increased water temperature. Scouring denudes the substratum, whereas elevated temperature results in stunted growth (Bridges and Anderson, 1984).

In 1988, the circulating water pump activity was low, resulting in little thermal loading and scouring effect. Results of the 1988 transect surveys showed such a increase in recolonization of the formerly denuded and stunted zones by *Chondrus*, in response to the continuing outage, that the divers were unable to detect boundaries of these zones, and no area measurements could be made.

In March and June 1989, divers were still unable to detect boundaries of the denuded or stunted zones, and no area measurements were made (BECO, 1990). In September and December, presumably in response to increased PNPS operations and the resultant scouring of the acute impact zone, boundaries began to be redefined and area measurements were made of the total impact zone.

During 1990, the boundaries between the stunted and denuded zones became more clearly defined, and areal measurements of both zones were made (Figure 12). The areas of the denuded and total acute impact zones in June 1990 were the highest seen since 1983. The dramatic increase in total affected area that occurred between April and June 1990 had not been seen before in the 1983-1990 period. The typical pattern seen prior to 1990 was that during the spring, with warmer temperatures and increased sunlight, algal growth flourishes, and the impact area declines even in years when the power plant is operating at high capacity. The pattern seen in 1990 was anomalous and permitted no ready explanation.

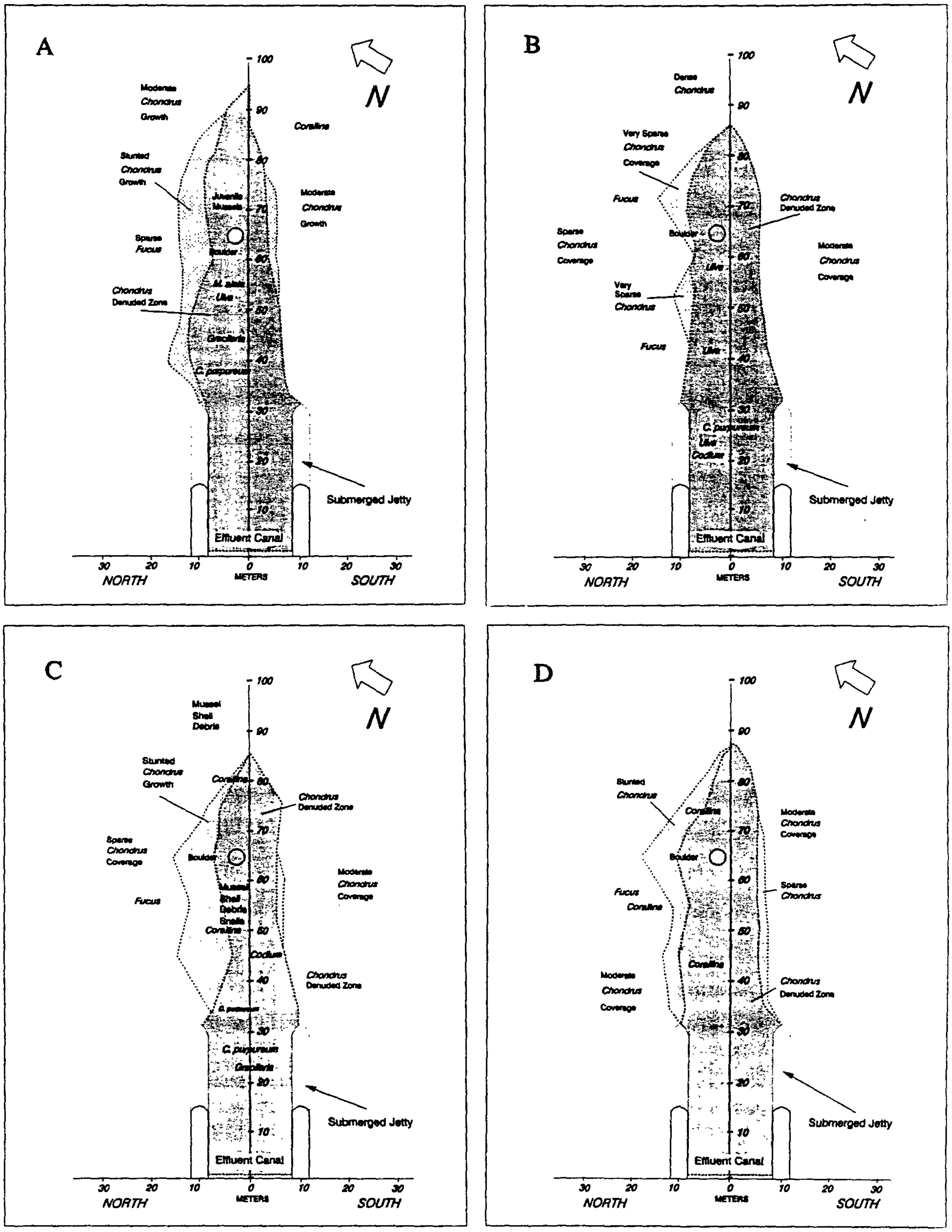

Figure 12. **Results of the 1991 Qualitative Transect Surveys of the PNPS Acute Impact Zone off the Discharge Canal. A, March; B, June; C, October; D, December.**

In 1991, the boundaries of the acute impact zone remained well-defined, except that in June there was no true stunted zone but only an area described by the divers as "sparse", that is, where the algal plants grew normally but were thinly distributed. From March to June, the total affected area and the *Chondrus* denuded zone decreased in area, a return to the typical pattern seen before 1990. This decrease in area continued through the October survey, perhaps aided by the May through July power plant outage. There was a slight increase in affected area in December.

CONCLUSIONS

Quantitative Faunal Studies

- Total number of species observed at the Effluent station is not related to plant operation, but may be related to habitat modification caused by changes in mussel populations. The total number of species at the Effluent station in the fall 1991 samples was the largest ever recorded at any of the stations.

- Total density fluctuations are strongly influenced by mussel populations. Unusually high mussel populations were observed in the vicinity of the discharge canal in June 1990. Mussels may have migrated to the site in response to higher temperature from the thermal discharge or by the currents. Greatly reduced densities in fall of 1991 are attributed to declines in mussel density.

- Species diversities declined at all stations in 1990, precluding any obvious effects of PNPS on area wide species diversity patterns. In 1991, however, species diversities were low in the spring, but greatly elevated in the fall, especially at the Effluent station.

- Community analysis using cluster analysis indicates that by September 1990, the Effluent station differed structurally from the two reference stations. Two species, one anemone and an amphipod were dominant at the Effluent station, but rare or absent elsewhere. This trend continued in 1991, with changes in abundances of individual species or groups of species being directly responsible for the different clustering patterns.

- A composite assessment of all benthic community parameters including species richness, diversity, and density taken together with community composition indicates that subtle alterations in the Effluent station are probably the result of PNPS operation. In some years these impacts result in higher densities and reduced species richness and diversity. In the fall of 1991, however, species richness and diversity were the highest ever recorded at the Effluent station.

Quantitative Algal Community Monitoring

- In October 1991, the algal community at the Effluent station differed more from the Manomet Point and Rocky Point stations than in March.
- The number of algal species shared (overlap) between the reference stations was lower, in March 1991, than that between the Effluent and reference stations. A return to the more typical pattern was seen in October when the overlap between the reference stations increased and became greater than that between the Effluent station and both reference stations.
- Algal biomass increased from September 1990 to March 1991 at the Effluent station and Manomet Point, a generally atypical pattern, and one similar to that observed in 1990. The expected seasonal increase in biomass between March and October occurred at all three stations.

Qualitative Transect Surveys

- The size of the denuded zone of the acute impact area was similar to that observed during earlier times of full power plant operation. Area of the denuded zone is mainly influenced by circulating water pump operation and the slight decrease in affected area seen from the March to October surveys may be explained by the three-month outage in May, June, and July 1991. Typically, the denuded zone decreases in area during the spring, a time of abundant algal growth; this pattern was observed in 1991.
- The warm-water alga, *Gracilaria tikvahiae*, was observed at the Effluent station during all four seasonal surveys; it was not observed at the reference stations.

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ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1991

Volume 1 of 2

(Results)

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B*	Mean monthly densities and range per 100 m^3 of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December 1975-1991.

*Available upon request.

SECTION I

EXECUTIVE SUMMARY

PNPS ichthyoplankton sampling was completed twice per month in January, February, October-December, weekly from March through September except that sampling occurred only twice in June due to circulating water system shutdown.

Numerical dominants among the 34 species represented in the catch by season included American plaice, sculpin, rock gunnel, and sand lance during winter-early spring; tautog, cunner, and mackerel during late spring-early summer; and rockling, hake, cunner, and windowpane during late summer-autumn.

Comparisons between 1991 monthly mean densities per 100 m^3 of water and those recorded over the 1975-1990 period suggest that Atlantic cod eggs were uncommon in February along with rockling, hake, and labrid eggs in June and July. In contrast, Atlantic mackerel eggs and larvae were found to be abundant in 1991 for the fourth consecutive year. Rock gunnel and sculpin larvae were relatively abundant in February. The distribution of tautog and cunner larval densities was unusual as they were both absent in July yet relatively abundant in September.

No lobster larvae were obtained in the 1991 collections. Only eleven have been taken in 18 years of sampling.

No unusually high densities warranting contingency sampling were observed in 1991.

SECTION II

INTRODUCTION

This report summarizes results of ichthyoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) discharge canal on a regular basis from January through December 1991. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 68006 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In an effort to condense the volume of material presented in this report, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECo.

SECTION III

METHODS AND MATERIALS

Entrainment sampling at PNPS was scheduled twice per month during January, February, October, November, December, and weekly March-September. Although weekly sampling was scheduled for June, PNPS began a refueling outage in May which resulted in both circulating water system pumps being out of service for much of June; samples were obtained on two occasions with a single CWS pump operating. All samples were collected in triplicate from rigging mounted approximately 30 meters from the headwall of the discharge canal (Figure 1), at low tide during daylight hours. A 0.333-mm mesh, 60-cm diameter plankton net affixed to this rigging was streamed in the canal for 8 to 12 minutes depending on the abundance of plankton and detritus. In each case, a minimum of 100 m^3 of water was sampled. Exact filtration volumes were calculated using a General Oceanics Model 2030R digital flowmeter mounted in the mouth of the net.

All samples were preserved in 10% Formalin-seawater solutions and returned to the laboratory for microscopic analysis. A detailed description of the analytical procedures may be found in MRI (1988).*

*Marine Research, Inc. 1988. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1987. III.C.1-6-10. In: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report No. 31. Boston Edison Company.

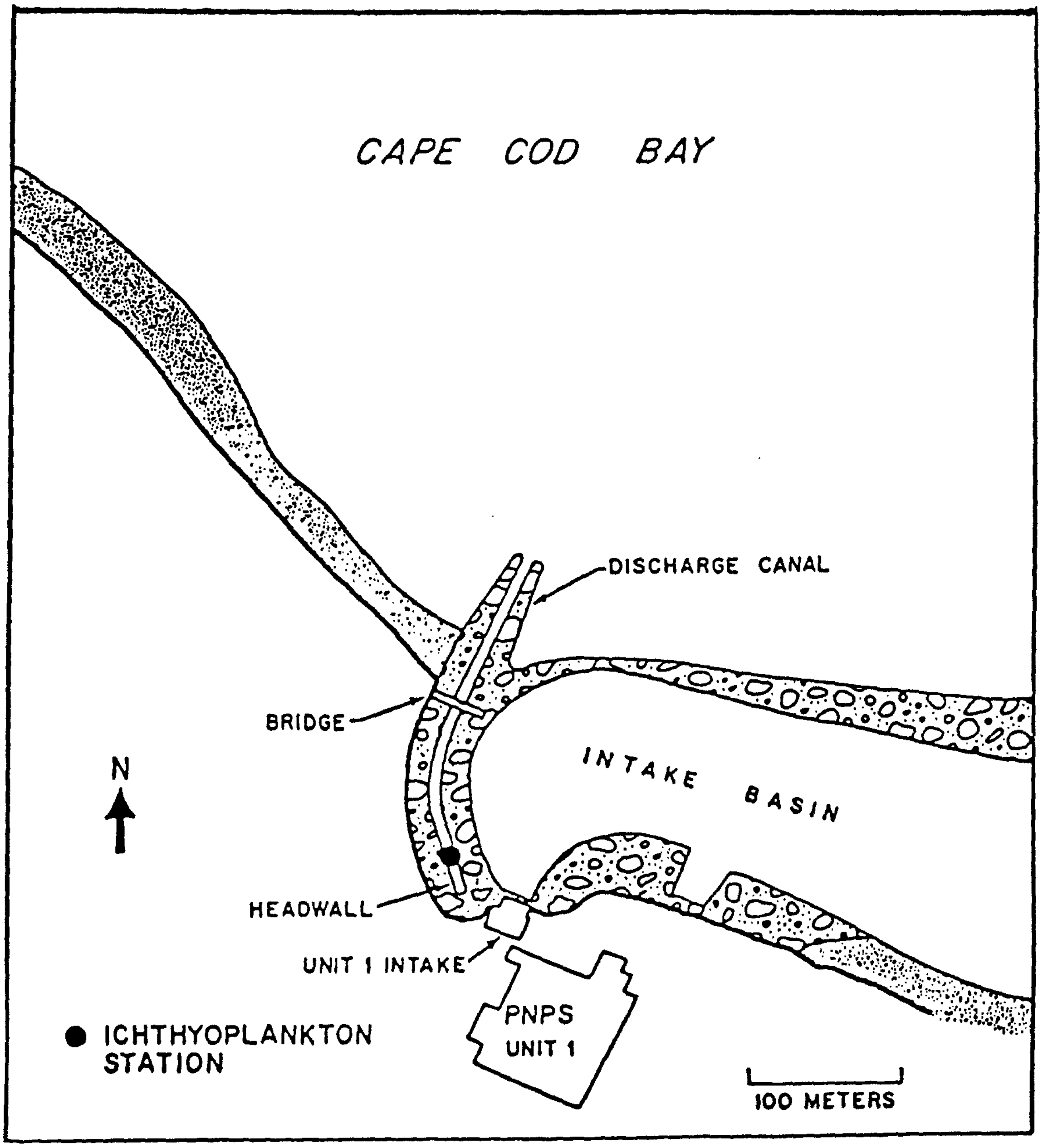


Figure 1. Entrainment sampling station in PNPS discharge canal.

When the Cape Cod Bay ichthyoplankton study was completed in 1976, a contingency sampling plan was added to the entrainment monitoring program. This plan was designed to be implemented if eggs or larvae of any dominant species proved to be "unusually abundant" in the PNPS discharge samples. The goal of this sampling plan was to determine whether circumstances in the vicinity of Rocky Point, attributable to PNPS operation, were causing an abnormally large percentage of ichthyoplankton populations there to be entrained or, alternatively, whether high entrainment levels simply were a reflection of unusually high population levels in Cape Cod Bay. "Unusually abundant" was defined as any mean density, calculated over three replicates, which was found to be 50% greater than the highest mean density observed during the same month from 1975 through 1990.

The contingency sampling plan consists of taking additional sets of triplicates from the PNPS discharge on subsequent dates to monitor the temporal extent of the unusual density. An optional offshore sampling regime was also established to study the spatial distribution of the species in question. The offshore contingency program consists of single, oblique tows at each of 13 stations (Figure 2) on both rising and falling tides for a total of 26 samples. Any contingency sampling requires authorization from Boston Edison Company.

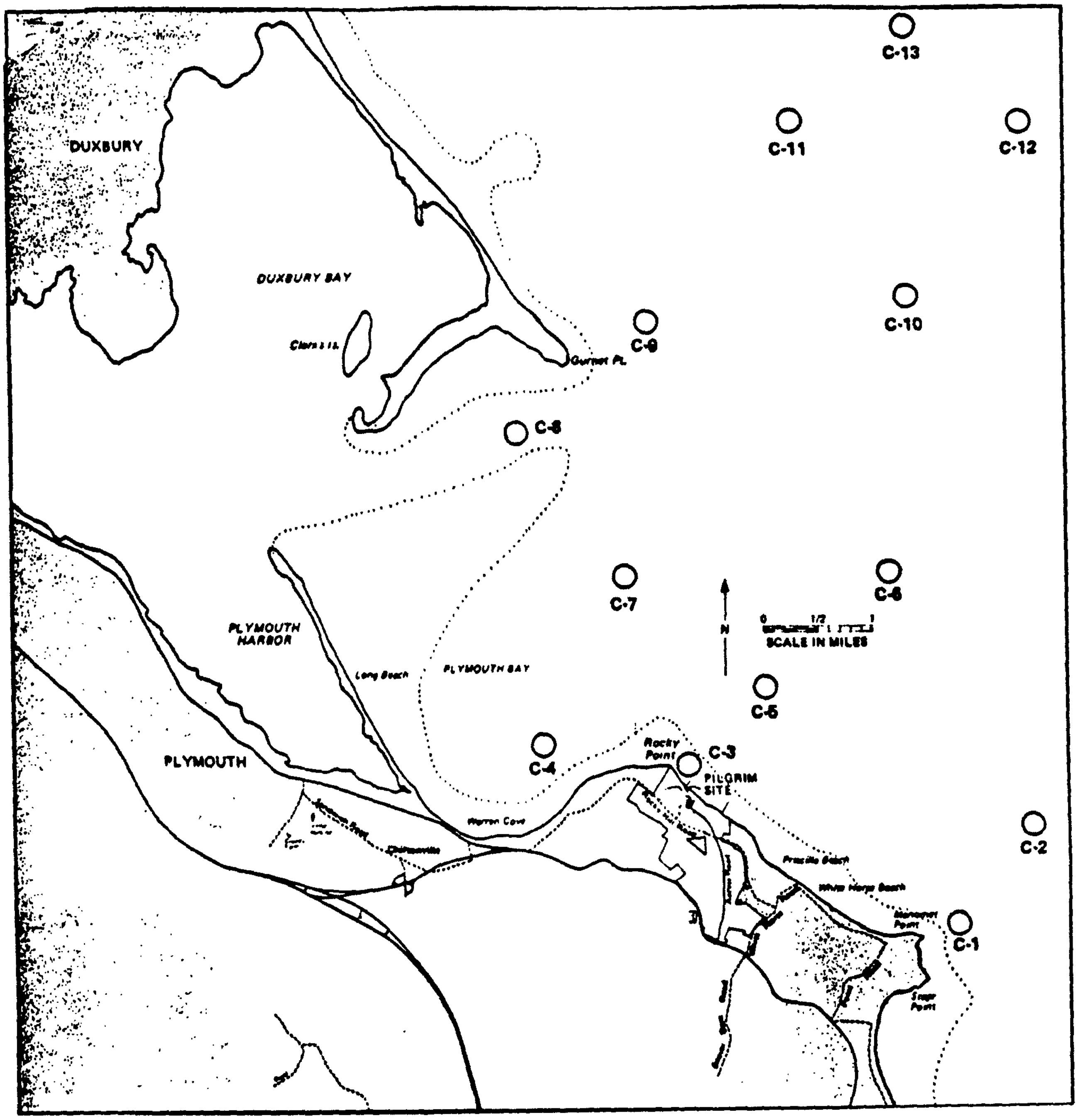


Figure 2. Location of entrainment contingency plan sampling stations, C-1 through C-13.

SECTION IV

RESULTS AND DISCUSSION

A. Ichthyoplankton Entrained - 1991

Population densities per 100 m^3 of water for each species listed by date, station, and replicate are presented for 1991 in Appendix A (available upon request). Table 1 lists all species represented in the 1991 collections, indicates the months eggs and/or larvae of each species were found and, for the more common species, the months of peak abundance.

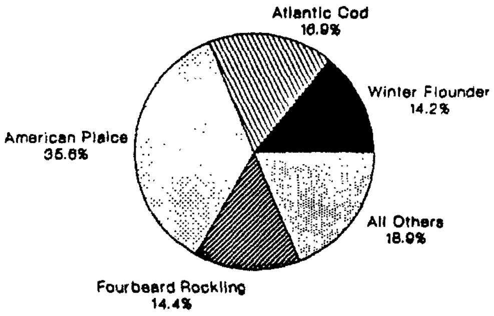
Ichthyoplankton collections are summarized below within the three primary spawning seasons observed in Cape Cod Bay: winter-early spring, late spring-early summer, and late summer-autumn. Figure 3 shows the dominant species of eggs and larvae within each season for 1991.

Winter-early spring spawners (December-April)

The beginning of this spawning season is sampled at the end of the calendar year. The two December 1991 collections produced four Atlantic cod eggs (*Gadus morhua*) and 15 Atlantic herring larvae (*Clupea harengus*). These counts resulted in respective monthly mean densities of 0.5 and 1.8 per 100 m^3 of water. The number of species represented in the earlier collections of the winter-early spring spawners was five in January, increasing to eight in February, twelve in March, and fifteen in April. Eggs were relatively uncommon since species

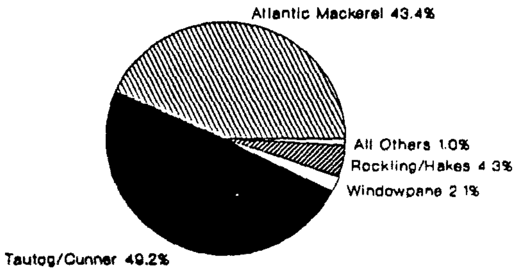
Figure 3. Dominant species of fish eggs and larvae found in PNPS ichthyoplankton samples by season. Percent of total and summed monthly means for all species are also shown.

Eggs
Winter-Early Spring Season
December-April



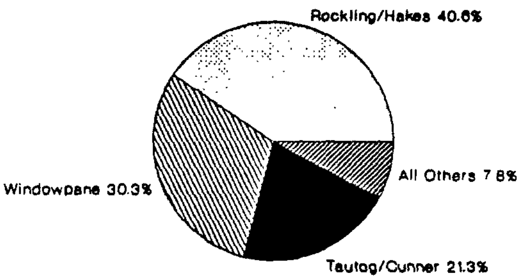
Sum of monthly means • 11.8 per 100 cubic meters

Late Spring-Early Summer Season
May-July



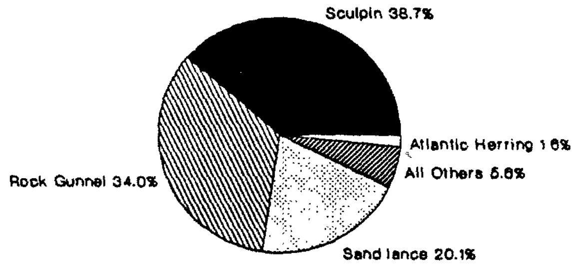
Sum of monthly means • 2330.8 per 100 cubic meters

Late Summer-Autumn Season
August-November



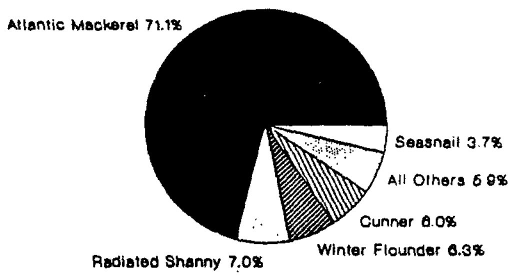
Sum of monthly means • 143.9 per 100 cubic meters

Larvae
Winter-Early Spring Season
December-April



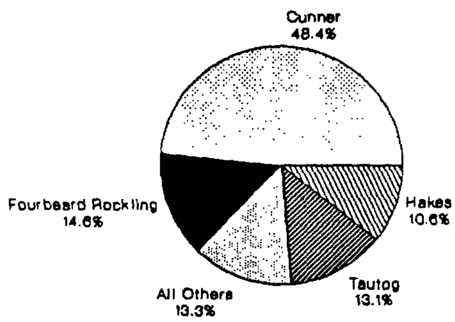
Sum of monthly means • 218.3 per 100 cubic meters

Late Spring-Early Summer Season
May-July



Sum of monthly means • 290.4 per 100 cubic meters

Late Summer-Autumn
August-November



Sum of monthly means • 42.6 per 100 cubic meters contributing most to entrainment during this period spawn demersal, adhesive eggs which are not generally subject to entrainment. They were in fact absent from the January and February collections. March samples contained small numbers of Atlantic cod, American plaice (Hippoglossoides platessoides), and winter flounder (Pleuronectes americanus) eggs. Monthly mean densities amounted to 0.3 per 100 m^3 for both cod and plaice, 0.1 per 100 m^3 for flounder. Since they are demersal and adhesive, winter flounder eggs are not typically entrained at PNPS. Their numbers in PNPS samples are therefore not considered representative of numbers in the surrounding area. Those that were taken were probably dislodged from the bottom by currents or perhaps other fish.

The number of species represented by larvae generally increased with time during the winter-early spring period; five species were taken in January, eight were taken in February, ten were taken in March, followed by eleven in April. Numerical dominants included the rock gunnel (Pholis gunnellus), grubby (Myoxocephalus aenaeus), and sand lance (Ammodytes sp.). Rock gunnel represented 63% of the January total, 60% of the February total, 30% of the March total, and 8% of the April total with monthly mean densities of 2, 46, 20, and 6 per 100 m^3 of water, respectively. Grubby did not appear in the collections until February when they accounted for 12% of the catch with a monthly mean density of 9 per 100 m^3. Grubby densities peaked in March with a mean density of 39 larvae per

100 m^3 accounting for 59% of the month's catch. They declined to 13 per 100 m^3 in April with a percent contribution of 19. Larval sand lance accounted for 2% of all larvae in January, 1% in February, 8% in March, and 55% in April; monthly mean densities were 0.1, 0.7, 5, and 38 per 100 m^3, respectively.

Late spring-early summer (May-July)

May, June, and July collections contained 20, 19, and 15 species, respectively. Among these totals, 11, 12, and 13 species were represented by eggs. Numerical dominants included the labrids (tautog, *Tautoga onitis*; cunner, *Tautogolabrus adspersus*) and Atlantic mackerel (*Scomber scombrus*). Assuming labrid-yellowtail eggs (*Pleuronectes ferrugineus*) were primarily labrid eggs, tautog and cunner contributed 33% of the total in May with a monthly mean density of 321 per 100 m^3, 54% of total in June with a monthly mean of 607 per 100 m^3, and 92% of total in July with a monthly mean of 219 per 100 m^3. Mackerel contributed an additional 56% to the May egg total with a monthly mean of 538 per 100 m^3 of water, 42% to the June total with a monthly mean of 473 per 100 m^3, dropping to 4% of the July total with a mean of 0.2 per 100 m^3.

Larval collections consisted of 15 species in both May and June, falling to 6 species in July. Atlantic mackerel, radiated shanny (*Ulvaria subbifurcata*), winter flounder, and cunner were numerically dominant. Mackerel accounted for 12 and 86% of the May and June larval catch with respective monthly mean densities of 7 and 200 per 100 m^3. Larval mackerel were absent from the July catch. Radiated shanny contributed 33% to the May total with a monthly mean of 19 per 100 m^3, dropping to 1% of the June total with a mean density of 2 larvae per 100 m^3. They were absent in July. Flounder and cunner were also absent in July but accounted for 19 and 1% of the May total and 1 and 7% of the June total, respectively. Corresponding monthly mean densities amounted to 16 and 2 per 100 m^3 for flounder and 0.3 and 17 for cunner in May and June.

Late summer-autumn spawners (August-November)

Both the number of species represented each month and overall densities typically decline steadily through this season. During 1991, 18 species were represented in August, 13 were represented in September, dropping to 3 in October and 6 in November. Species represented by eggs amounted to 12 in August, 10 in September, 3 in October, and 2 in November. Rockling and hake (Enchelyopus cimbrius, Urophycis spp.), windowpane (Scophthalmus aquosus), and tautog/cunner were the numerical dominants among the eggs. Rockling and hake accounted for 40, 43, 70, and 82% of the four respective monthly egg totals with monthly mean densities of 48, 9, 1, and 0.4 per 100 m^3 of water. Windowpane, assuming they accounted for most of the grouped Paralichthys-Scophthalmus eggs, contributed an additional 29% to the August total with a monthly mean of 35 per 100 m^3 of water, 41% to the September total with a mean of 9 per 100 m^3, and 18% to the October total with a mean of 0.3 per 100 m^3. They were absent from the November collections. Tautog and cunner were present only in August and September when they represented 25 and 2% of all eggs with monthly mean densities of 30 and 0.4 per 100 m^3.

Late summer-autumn larval collections contained 13 species in August, 11 in September, 1 in October, and 4 in November. Seasonal dominants included cunner, rockling, tautog, and hake. Cunner appeared only in August and September when they accounted for 63 and 37% of the larval catch with monthly mean densities of 13 and 8 per 100 m^3, respectively. Rockling added 12 and 17% to the respective August and September totals, as well as representing all of the small number of larvae taken in October; they were absent in November. Monthly mean densities were 2, 3, and 0.4 per 100 m^3 during the three respective months. Tautog and hake contributed 6 and 5% to the August total, 20 and 16% to the September total with respective mean densities per 100 m^3 of water of 1 and 1 in August, 4 and 3 in September. Both tautog and hake were absent from the October samples, hake also from the November samples. A single larval tautog was taken in November representing a monthly mean of 0.2 per 100 m^3.

B. Multi-year Ichthyoplankton Comparisons

Table 2 presents a master species list for ichthyoplankton collected from the discharge canal at PNPS and indicates the years each species was taken from 1975 through 1991. The general period of occurrence within the year is also indicated for each species including the peak period for the numerical dominants. A total of 34 species was represented in the 1991 collections, below the overall average of 38 and equal to the low value of 34 observed in 1984 when both CWS pumps were out of service from April through August. No new species were added to the overall list in 1991.

Monthly mean densities per 100 m^3 of water were calculated for each of the 13 numerically dominant fish eggs or fish egg groups, those accounting for 99.3% of the 1991 egg total, as well as total eggs (all species combined) for each year from 1975 through 1991 (Appendix B, available upon request). To help compare values over the 17-year period, egg data were plotted in Figure 4. For this figure cod and pollock (Pollachius virens) eggs were combined with the gadid-Glyptocephalus group, rockling and hake were combined with the Enchelyopus-Urophycis-Peprilus group, and labrids and yellowtail were combined with the labrid-Pleuronectes group. For each category shown, the highest monthly means obtained from 1975 through 1990 were joined by solid lines as were the lowest monthly means, and the area between was shaded, indicating the range of these values. Monthly mean values for 1991 were joined by a dashed line. Appendix B and Figure 5 contain comparable data for the eleven numerically dominant species of fish larvae, those accounting for 96.1% of the 1991 catch, as well as total larvae (all species combined). Low values obtained for both eggs and larvae during April through August of 1984 and 1987 were excluded from these figures and the following discussion because exceptionally low values were common then, probably due to low through-plant water volumes (see Impact section).

Based on these data, egg densities for Atlantic menhaden (Brevoortia tyrannus), searobins (Prionotus spp.), Paralichthys-Scophthalmus group, and American plaice were well within the range of monthly mean densities observed over the previous 16 years. Among the numerically dominant larvae, fourbeard rockling, sculpins (Myoxocephalus spp.), seasnails (Liparis spp.), radiated shanny, sand lance, and winter flounder were also within the range of monthly mean densities recorded over past years. Among the remaining eggs and larvae, the following observations were made:

1. Atlantic cod eggs were absent in February for the fourth consecutive year. Prior to 1988 they were taken every year in February although not in high numbers (1 to 3 per 100 m^3 of water).
2. Atlantic mackerel eggs have been abundant in June during the past three seasons. In June 1991 (monthly mean = 473 per 100 m^3) their numbers declined compared with 1988 (2220 per 100 m^3), 1989 (1013 per 100 m^3), and 1990 (2081 per 100 m^3); however densities continued to rank well ahead of 1975-1987 when means ranged from 5 (1976) to 277 (1986) per 100 m^3. Mackerel larvae were also relatively common in May (6.6 per

100 m^3) and June (200 per 100 m^3) 1991. May's mean density surpassed all previous May values, 1979 being the previous high with 6.1 larvae per 100 m^3. June's density ranked second, exceeded only by the 1981 value of 318 per 100 m^3.

3. In contrast fourbeard rockling eggs and the hakes (combined with the Enchelyopus-Urophycis-Peprilus group) were uncommon in June and July 1991. Combining rockling and hake with the Enchelyopus-Urophycis-Peprilus group showed respective monthly mean densities of 10 and 6 per 100 m^3 in June and July. Previous low values were 18 for June (1982) and 21 for July (1986).

4. Similar results were obtained for labrid eggs. Combined with the labrid-yellowtail group which they no doubt dominate in summer, 1991 monthly means for both June (607 per 100 m^3) and July (219 per 100 m^3) ranked below all previous values for those months. Previous low values were 733 per 100 m^3 for June in 1980 and 452 per 100 m^3 for July in 1986.

5. Rock gunnel and sculpin larvae were abundant in February. For rock gunnel February 1991 (46 per 100 m^3) ranked ahead of all previous February values, 1985 showing the previous high with a mean density of 25 per 100 m^3. For sculpin a mean density of 30 per 100 m^3 in February 1991 exceeded all previous February periods except 1988 with 41 per 100 m^3. Interestingly, in both high-density years shorthorn sculpin (Myoxocephalus scorpius) accounted for most of the sculpin larvae taken

during February. In all other years they were uncommon or absent.

6. Larval tautog and cunner were both absent from the July 1991 collections, were within the normal range in August, and relatively abundant in September. Tautog were absent from July collections in only two previous years, in both cases (1984, 1987) when both CWS pumps were off (see Impact section). While not absent, they were uncommon in July 1975 (0.1 per 100 m^3) and 1982 (0.3 per 100 m^3). The mean September density for tautog (4.2 per 100 m^3) exceeded the previous high mean of 3.8 per 100 m^3 recorded in 1975. A single tautog larva was also collected in November 1991 (density = 0.2 per 100 m^3), the first time one has been recorded that late in the year. Cunner were absent from the July collections only one other year, 1987 when no CWS pumps were running. Their mean density in September 1991 (6.6 per 100 m^3) exceeded the previous high (4.9 per 100 m^3) recorded in 1980.

Although several of the above monthly mean densities exceeded all other corresponding means, no densities meeting the unusually high definition of the contingency sampling plan were encountered during 1991.

Ichthyoplankton populations sampled over a long time series typically display density variations of one order of magnitude, and two orders of magnitude are not unheard of (see Figures 4 and 5). Variations in spawning stock size and condition, food availability, predator densities, and physical variables such as water temperature and wind all contribute to the level of observed ichthyoplankton densities. In many cases the 1991 monthly densities which extended above or below all previous values at PNPS did so only slightly. In cases such as mackerel eggs which have been entrained in relatively high numbers for four years, the data probably reflect relatively strong stock biomass (NOAA 1991) *. Likewise persistently low densities of Atlantic cod eggs noted from 1988 through 1990 are consistent with a regional downturn in the size of the spawning population (NOAA 1991).

C. Lobster Larvae Entrained

No larval lobsters (*Homarus americanus*) were found in the 1991 entrainment samples. Following is a summary of previous lobster larvae collections at PNPS, a total of 11 having been taken.

1990: 2 larvae - 1 stage I, June 26; 1 stage IV August 23.
1983-1989: none found.
1982: 1 larva - stage I on June 14.
1981: 1 larva - stage IV on June 29.
1980: none found.
1979: 1 larva - stage I on July 14.
1978: none found.
1977: 3 larvae - 1 stage I, June 10; 2 stage I, June 17.
1976: 2 larvae - 1 stage I, July 22; 1 stage IV-V, August 5.
1975: 1 larva - stage I, date unknown.
1974: none found.

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*NOAA (National Oceanic and Atmospheric Administration). 1991. Status of the fishery resources off the northeastern United States for 1990. NOAA Technical Memorandum NMFS-F/NEC-81.

The lobster larvae collected in 1976 were obtained during a more intensive lobster larvae program which employed a 1-meter net, collecting relatively large sample volumes, in addition to the standard 60-cm plankton net (Marine Research 1977).** Both larvae taken in 1976 were collected in the meter net; none were found in the routine ichthyoplankton samples.

**Marine Research, Inc. 1977. Entrainment investigations and Cape Cod Bay Ichthyoplankton Studies, July-September 1976. III.C.1-1-71. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 9. Boston Edison Company.

SECTION V

HIGHLIGHTS

1) Atlantic cod eggs were absent from the February 1991 collections for the fourth consecutive year. Recent low densities are consistent with a regional downturn in the size of the spawning population.

2) In contrast Atlantic mackerel eggs remained abundant in June 1991 as in June 1988, 1989, and 1990. Recent high egg counts probably reflect relatively strong stock biomass. May and June 1991 mackerel larval densities were also relatively high.

3) Fourbeard rockling, hakes, and labrid eggs were uncommon in June and July. In each case mean monthly densities for 1991 ranked below corresponding values observed during previous years dating back to 1975.

4) Rock gunnel and sculpin larvae were relatively abundant in February 1991. The February 1991 density for rock gunnel exceeded all previous February values while that for sculpin exceeded every other February but one. Shorthorn sculpin contributed the majority of larval sculpin during both high-ranking years.

5) Larval tautog and cunner were both absent from the July 1991 collections. This occurred only two other years for tautog, in both cases when both CWS pumps were off. Similarly cunner were absent from the July catch only one other year, also when both CWS pumps were off. September 1991 mean densities for

both tautog and cunner exceeded all previous September values by a small margin.

6) No lobster larvae were obtained in the 1991 ichthyoplankton collections.

7) No unusually high densities requiring contingency sampling were recorded in 1991.

Figure 4. Mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1991 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1990 period.

Brevoortia tyrannus

Gadidae-Glyptocephalus

Enchelyopus-Urophycis Peprilus

Prionotus spp.

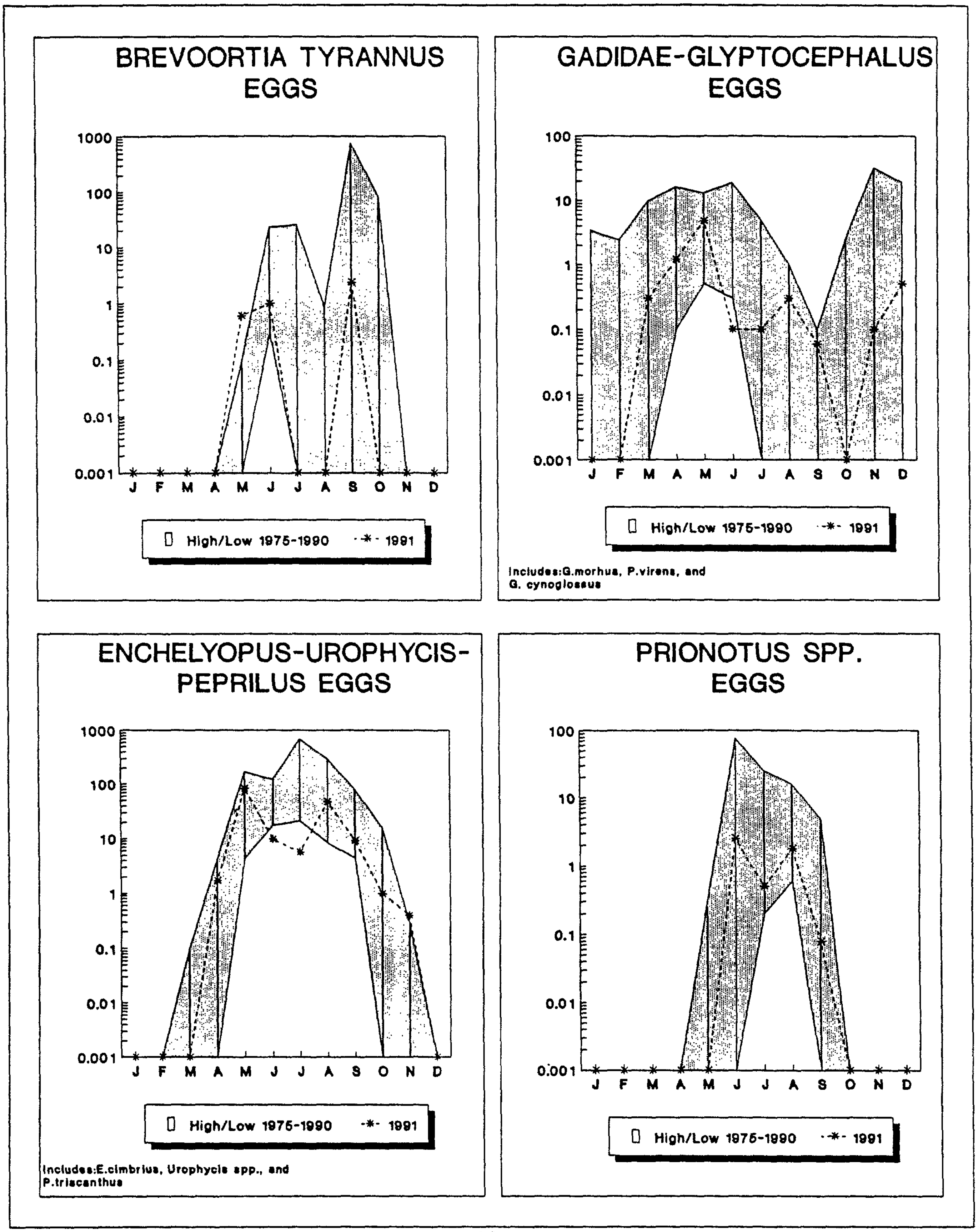
Labridae-Pleuronectes

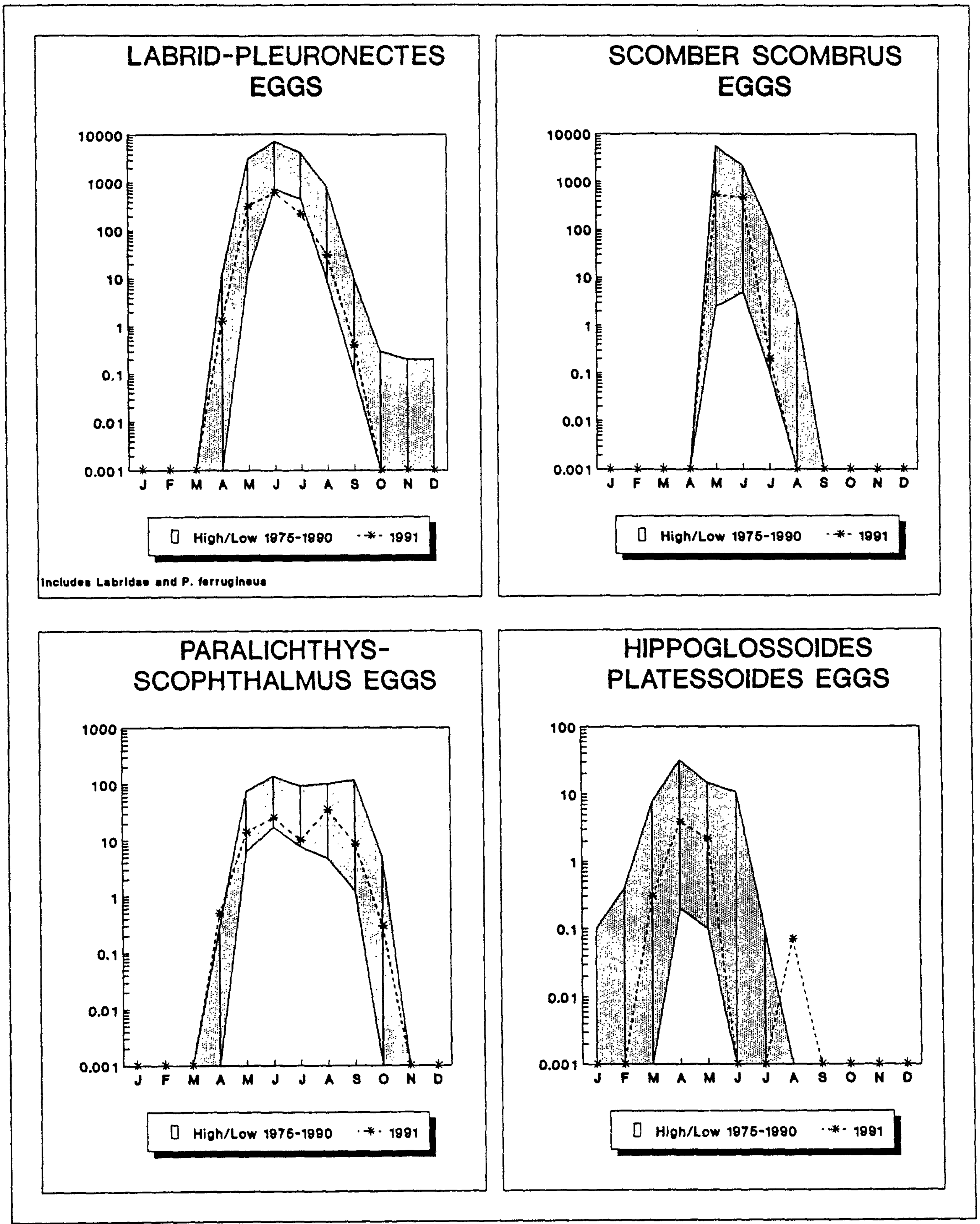
Scomber scombrus

Paralichthys-Scophthalmus

Hippoglossoides platessoides

Total eggs


BREVOORTIA TYRANNUS EGGS
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
GADIDAE-GLYPTOCEPHALUS EGGS
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
Includes:G.morhua, P.virens, and G. cynoglossus
ENCHELYOPUS-UROPHYCIS-PEPRILUS EGGS
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
Includes:E.cimbrius, Urophycis spp., and P.triacanthus
PRIONOTUS SPP. EGGS
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991


LABRID-PLEURONECTES EGGS
10000
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
Includes Labridae and P. ferrugineus
SCOMBER SCOMBRUS EGGS
10000
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
PARALICHTHYS-SCOPHTHALMUS EGGS
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
HIPPOGLOSSOIDES PLATESSOIDES EGGS
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991

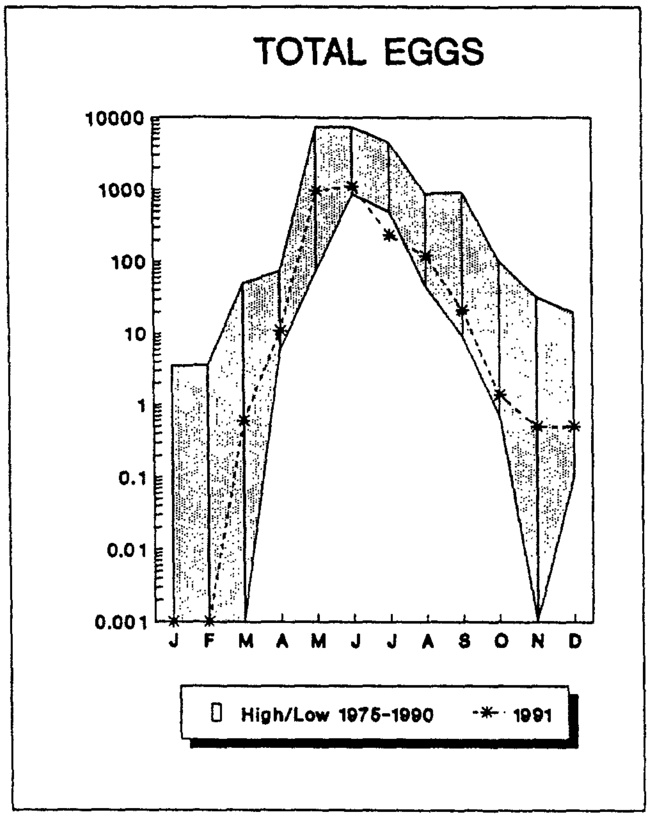

TOTAL EGGS
10000
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991

Figure 5. Mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eleven numerically dominant larval species and total larvae, 1991 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1990 period.

Clupea harengus

Enchelyopus cimbrius

Myoxocephalus spp.

Liparis spp.

Tautoga onitis

Tautogolabrus adspersus

Ulvaria subbifurcata

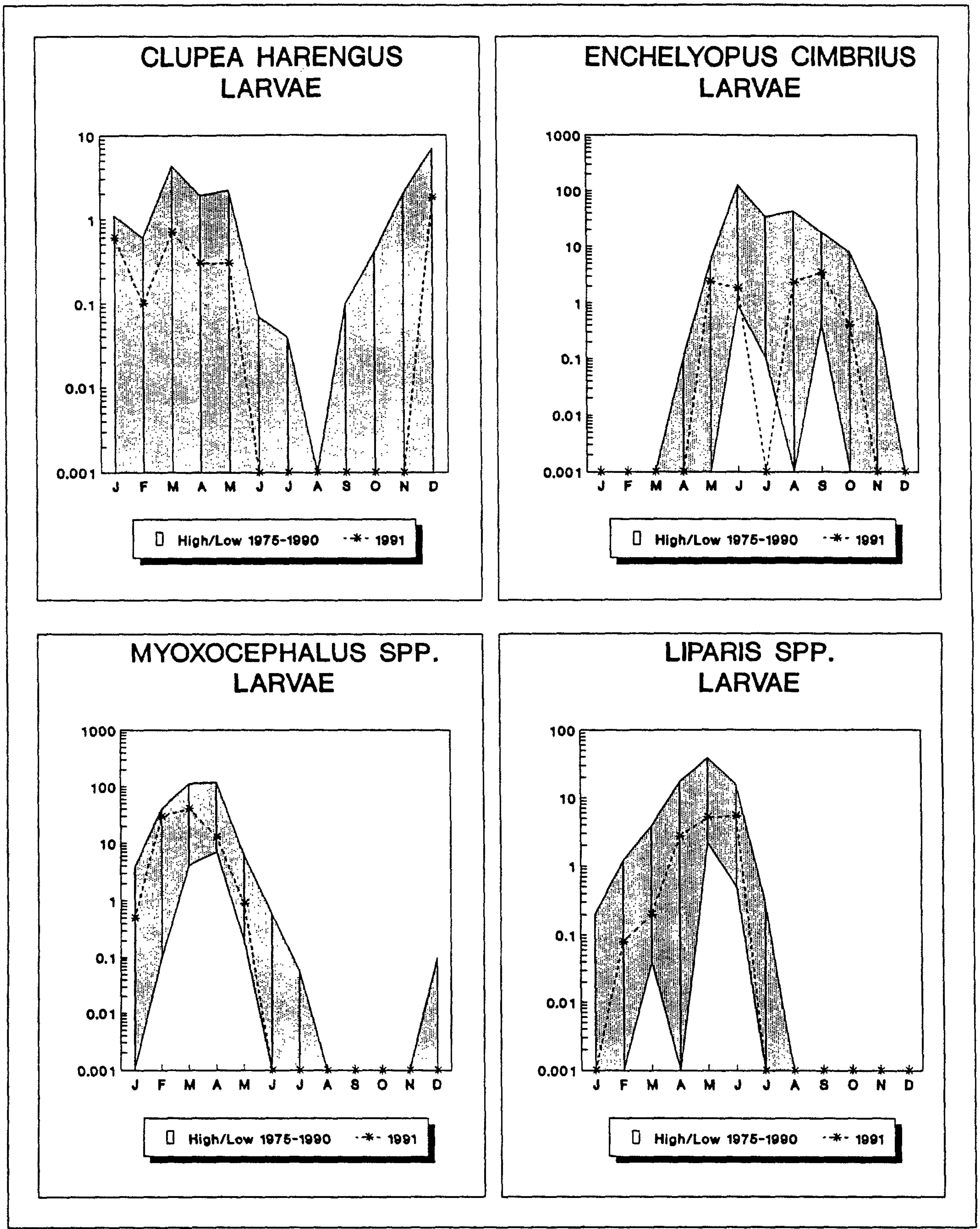
Pholis gunnellus

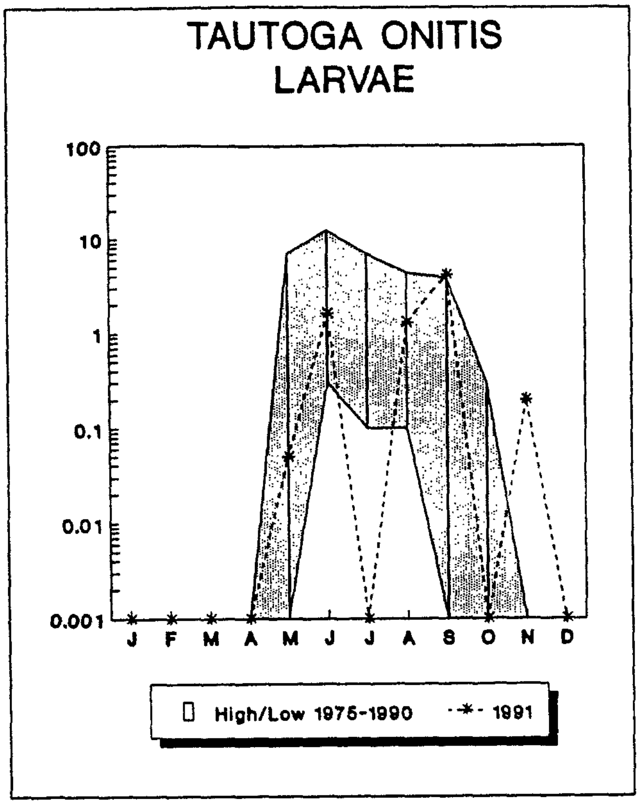
Ammodytes sp.

Scomber scombrus

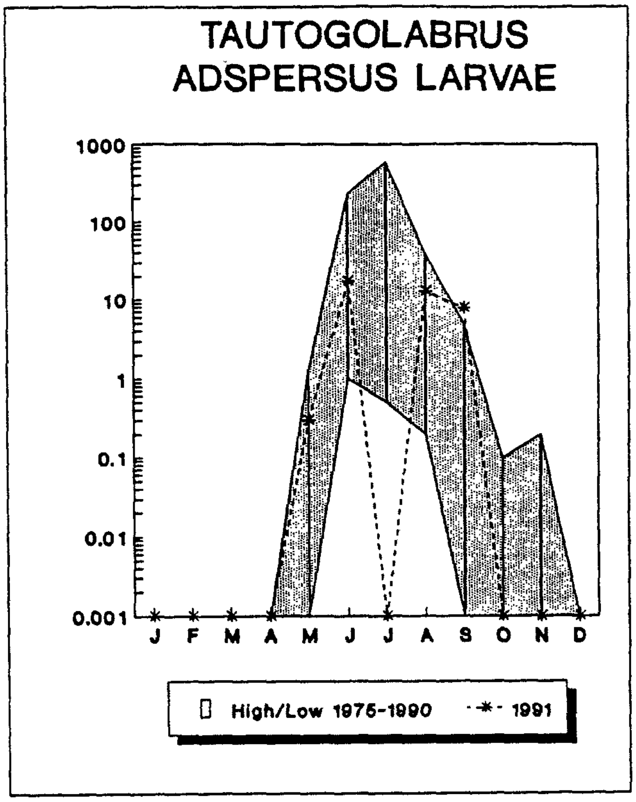
Pleuronectes americanus

Total larvae

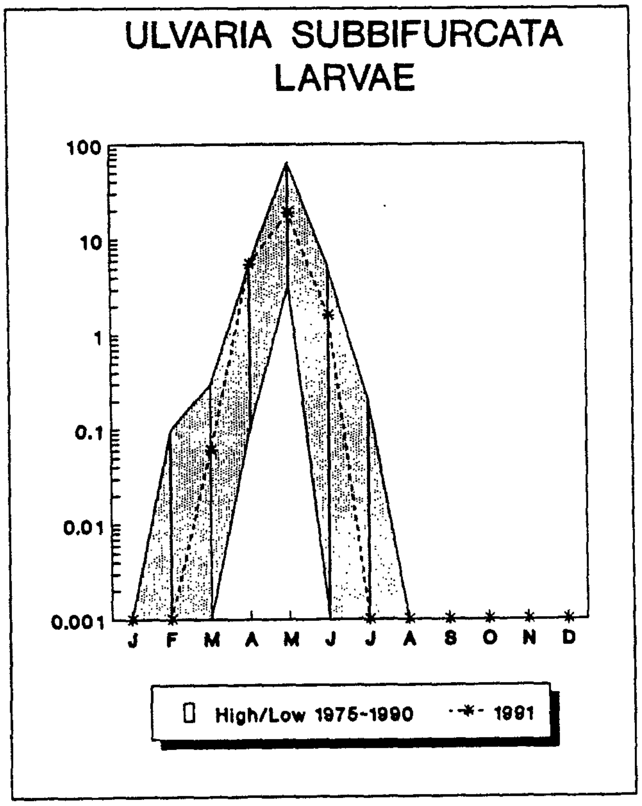

CLUPEA HARENGUS LARVAE
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
ENCHELYOPUS CIMBRIUS LARVAE
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
MYOXOCEPHALUS SPP. LARVAE
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991
LIPARIS SPP. LARVAE
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991



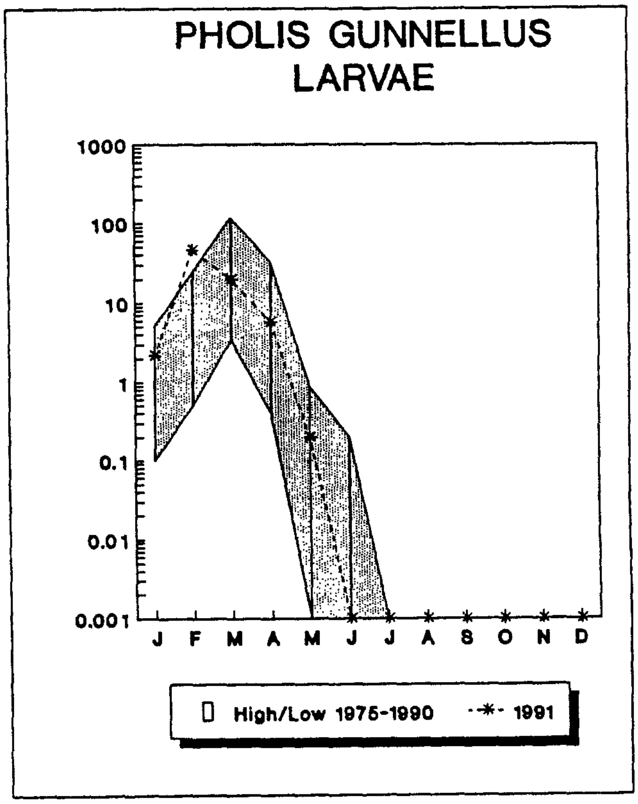
TAUTOGA ONITIS
LARVAE
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991



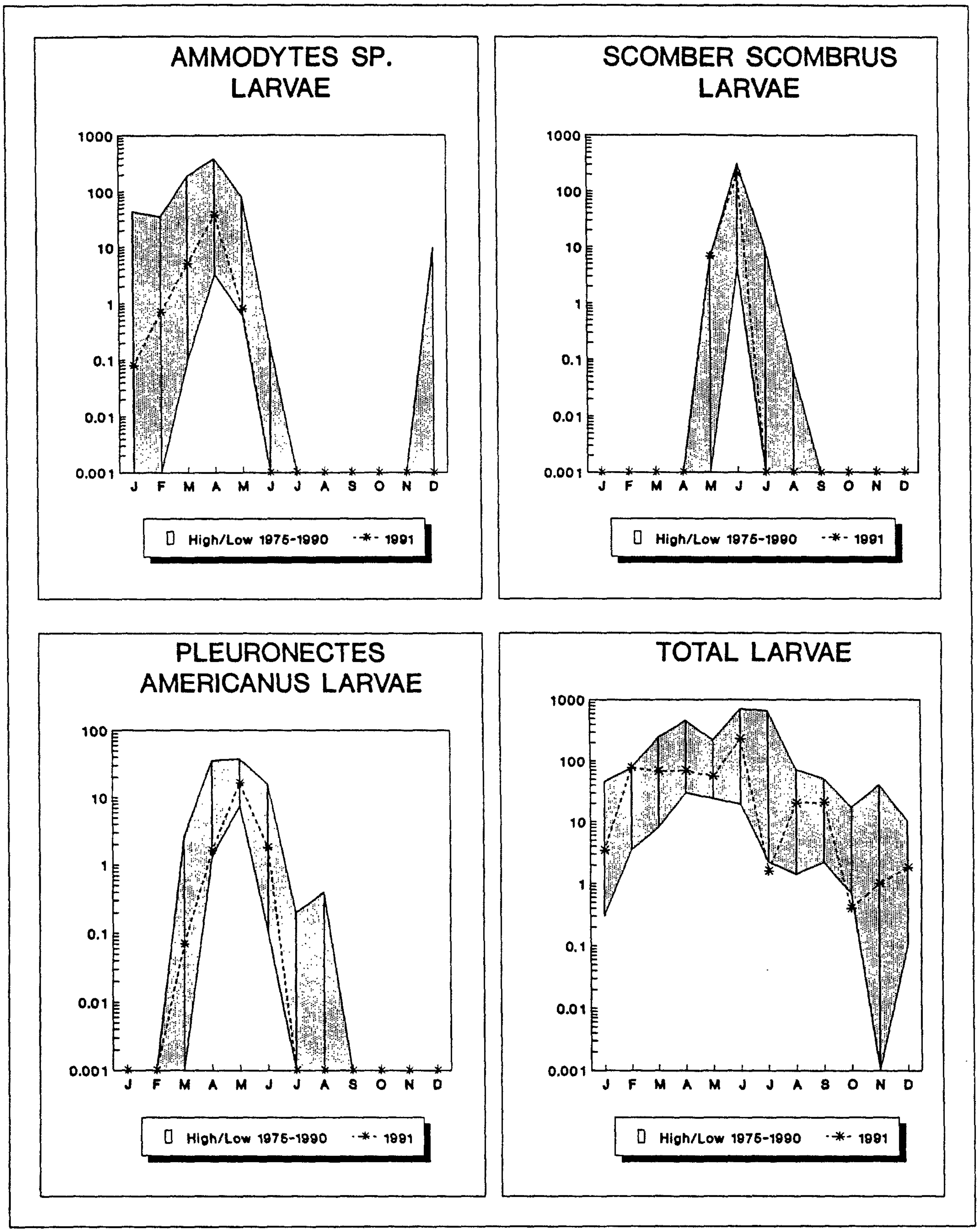
TAUTOGOLABRUS
ADSPERSUS LARVAE
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991



ULVARIA SUBBIFURCATA
LARVAE
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991



PHOLIS GUNNELLUS
LARVAE
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991



AMMODYTES SP. LARVAE
SCOMBER SCOMBRUS LARVAE
PLEURONECTES AMERICANUS LARVAE
TOTAL LARVAE
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
High/Low 1975-1990
1991

Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December 1991. Lines indicate peak periods for the more abundant species.

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic menhaden	Brevoortia tyrannus					E	E L			E		L	
Atlantic herring	Clupea harengus	L	L	L	L	L							L
Bay anchovy	Anchoa mitchilli							E	E	E			
Anchovy	Anchoa spp.							L	L	L			
Fourbeard rockling	Enchelyopus cimbrius				E	E L	E L	E	E L	E L	E L	E	
Atlantic cod	Gadus morhua			E	E L	E L	L		L	E		E	E
Silver hake	Merluccius bilinearis						E		E L	E L	E		
Pollock	Pollachius virens	L	L			L							
Hakes	Urophycis spp.						E	E L	E L	E L			
Goosefish	Lophius americanus				E	E	E						
Silversides	Menidia spp.					L	E L	L				L	
Northern pipefish	Syngnathus fuscus						L	L	L	L			
Searobins	Prionotus spp.						E	E	E	E			

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grubby	Myoxocephalus aenaeus		L	L	E L	L							
Longhorn sculpin	M. octodecemspinosus	L	L		L								
Shorthorn sculpin	M. scorpius	L	L	L	L								
Seasnail	Liparis atlanticus			L	L	L	L						
Gulf snailfish	L. coheni		L	L									
Scup	Stenotomus chrysops							L	L				
Wrasses	Labridae					E	E	E	E	E			
Tautog	Tautoga onitis					L	L		L	L		L	
Cunner	Tautogolabrus adspersus					L	L		L	L			
Radiated shanny	Ulvaria subbifurcata			L	L	L	L						
Rock gunnel	Pholis gunnellus		L	L	L	L							
Wrymouth	Cryptacanthodes maculatus			L									
Sand lance	Ammodytes sp.	L	L	L	L	L							
Atlantic mackerel	Scomber scombrus					E L	E L	E					
Butterfish	Peprilus triacanthus							E	E	E L			

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Smallmouth flounder	Etropus microstomus							E	E				
Fourspot flounder	Paralichthys oblongus*							E L	L	L			
Windowpane	Scophthalmus aquosus*				E	— E —	E — L	E —	E — L	E — L	E		
Witch flounder	Glyptocephalus cynoglossus					E	E L	E	E				
American plaice	Hippoglossoides platessoides			E	— E — L	E — L	L		E				
Winter flounder	Pleuronectes americanus			E L	E L	E — L —	L						
Yellowtail flounder	P. ferrugineus				E	E	E L	E	E L				
Hogchoker	Trinectes maculatus							E					

*Although these eggs were not identified specifically, they were assumed to have occurred as shown based on larval abundance.

Table 2. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1991. General periods of occurrence for eggs and larvae combined are shown along the right side; for the dominant species, periods of peak abundance are also shown in parentheses.

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Period of Occurrence
Anguilla rostrata	J*	J	J		J	J								J		J		Feb - Jun
Alosa spp.		L	L	J	L						L					J		May - Jul
Brevoortia tyrannus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Oct)Dec
Clupea harengus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan - Dec**
Anchoa spp.	L		L	L	L		L	L	L	L	L	L	L	L	L	L	L	Jun - Sep
A. mitchilli			E	E	E		E	E/L			E	E			E	E	E	Jun - Sep
Osmerus mordax	L	L	L	L	L		E/L	L	L		L	L	L	L	E/L			Apr - Jun
Brosme brosme	E/L	E/L	E/L		E/L	E/L	E	E	E									Apr - Jul
Enchelyopus cimbrius	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Sep)Dec
Gadus morhua	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Nov) - (Dec)Dec
Melanogrammus aeglefinus	L	E/L	E/L	E/L	L				L		E			E		E		Apr - Jul
Merluccius bilinearis	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	May(May) - (Jun)Nov
Microgadus tomcod			L	L		L	L	L	L	L	L	L	L	L	L	L		Jan - May
Pollachius virens	E/L	E/L	E	E/L	E/L	E/L	L			L	E/L	L	E/L	L	L	L	L	Jan-Jun,Nov,Dec
Urophycis spp.	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Aug) - (Sep)Nov
Ophidiidae-Zoarcidae	L																	Sep
Lophius americanus	E/L	E	E/L	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E	E	E	E/L	E/L	E/L	May - Oct
Strongylura marina			L															Jul
Fundulus spp.		E	E															Jul
F. heteroclitus					E													Jun
F. majalis					J													Oct
Menidia spp.		L	L	L	L	E/L	E/L	E	E/L	L	L	L	L	L	L	L	L	May - Sep
M. menidia	E/L	E/L	E						L								E	May - Sep
Syngnathus fuscus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Apr - Oct

*J = juvenile.
**Absent August and September; peaks = March-May and November-December.

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Period of Occurrence
Sebastes norvegicus															L			Jun
Prionotus spp.	E/L	E		E	E	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E	E	E	May(Jun) - (Aug)Sep
Myoxocephalus spp.	L	L	L	L	L	L	L	L	E/L	L	E/L	L	L	L	E/L	L	E/L	Dec(Mar) - (Apr)Jul
M. aenaeus					L	L	L	L	L	L	L	L	L	L	L	L	E/L	Jan(Mar) - (Apr)Jul
M. octodecemspinosus						L	L	L	L	L	L	L	L	L	E/L	L	L	Jan(Mar) - (Apr)May
M. scorpius						L	L	L		L	L	L	L	L	L	L	L	Feb - Apr
Aspidophoroides monopterygius						L	L	L								L		Mar - Apr
Cyclopterus lumpus		L	L				L	L	E		L		L	L	L	E/L		Apr - Jul
Liparis spp.	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Apr) - (Jun)Jul
L. atlanticus							L	L	L	L	L	L	L	L	L	L	L	Mar(Apr) - (Jun)Jul
L. coheni							L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Mar)Apr
Centropristis striata	L					L			L	L	L	L	L	L	L	L		Jul - Oct
Cynoscion regalis						L					L	L						May - Sep
Stenotomus chrysops	L		L											L	E	L	L	Jun - Jul
Menticirrhus saxatilis	L				L													Jul - Aug
Labridae	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Mar(May) - (Aug)Sep
Tautoga onitis	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Tautogolabrus adspersus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Lumpenus lumpretaeformis	L						L			L	L	L		L	L	L		Jan - Jun
Ulvaria subbifurcata	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Feb(Apr) - (Jun)Oct
Pholis gunnellus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Apr)Jun
Cryptacanthodes maculatus				L	L		L	L	L	L	L	L			L	L	L	Feb - Apr
Ammodytes sp.	L	L	L	L	E/L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Mar) - (May)Jun
Gobiosoma ginsburgi	L		L					L						L				Jul - Aug
Scomber scombrus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Jul)Sep
Peprilus triacanthus	E/L	E/L	E/L	E	E	E/L	E/L	L	E/L	E/L	L		E	E/L	E/L	L	E/L	May - Oct

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Period of Occurrence
<u>Etropus</u> <u>microstomus</u>	L								L		E	E/L	E		E		E	Jul - Oct
<u>Paralichthys</u> <u>dentatus</u>	E/L								E/L		L		E/L	E		L		Sep - Nov
<u>P</u>. <u>oblongus</u>*		E/L	E/L		E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	May - Oct
<u>Scophthalmus</u> <u>aquosus</u>*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Sep)Oct
<u>Glyptocephalus</u> <u>cynoglossus</u>	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Mar(May) - (Jun)Nov
<u>Hippoglossoides</u> <u>platessoides</u>	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Mar) - (Jun)Nov
<u>Pleuronectes</u> <u>americanus</u>	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Apr) - (Jun)Aug
<u>P</u>. <u>ferrugineus</u>	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Feb(Apr) - (May)Nov
<u>P</u>. <u>putnami</u>							L	E/L										Mar - Jun
<u>Trinectes</u> <u>maculatus</u>			E	E			E	E				E		E	E/L	E/L	E	May - Sep
<u>Sphoeroides</u> <u>maculatus</u>			L								L							Jul - Aug
Number of Species**	41	36	43	35	37	35	40	38	37	34	42	37	36	41	40	42	34	

*Although these eggs were not identified specifically, they were assumed to have occurred as shown based on the occurrence of larvae.
**For comparative purposes three species of <u>Myoxocephalus</u> were assumed for 1975-1978 and two species of <u>Liparis</u> for 1975-1980.

APPENDIX A*

Densities of fish eggs and larvae per 100 m^3 of water recorded in the PNPS discharge canal by species, date, and replicate, January-December 1991.

*This Appendix is available upon request.

APPENDIX B*

Mean monthly densities and range per 100 m^3 of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December, 1975-1991.

*This Appendix is available upon request.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1991

Volume 2 of 2

(Impact Perspective)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 4, 1992

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SECTION I

EXECUTIVE SUMMARY

Entrainment sampling at the Pilgrim Nuclear Power Station (PNPS) discharge canal was scheduled twice per month during January, February, October-December; weekly March through September. Sampling occurred only twice in June due to circulating water system shutdown. PNPS operated at 58% capacity in 1991; a refueling outage resulted in sampling with only one of two circulating water system pumps in operation from May through July.

Ichthyoplankton densities meeting the "unusually abundant" criterion defined under the contingency sampling program were not recorded in 1991, the last occasion being in February and March 1988. Based on full load flow capacity, total numbers of eggs which may have been entrained by PNPS in 1991 were estimated to range from 2.1 million for Atlantic menhaden to 628.7 million for the labrid-yellowtail group. Corresponding values among the eleven dominant larval species ranged from 2.0 million for Atlantic herring to 108.2 million for Atlantic mackerel.

Recent declines in abundance of cunner, windowpane, yellowtail flounder, and winter flounder in collections around PNPS appear to be widespread and therefore unlikely to be directly related to entrainment of eggs and larvae.

An analysis of egg and larval entrainment between years with differing pump regimes indicates that larval entrainment and perhaps even egg entrainment are directly related to water withdrawal rates.

No lobster larvae were collected in PNPS entrainment samples in 1991.

SECTION II

INTRODUCTION

This report addresses results of PNPS ichthyoplankton entrainment sampling in relation to potential impact assessment. Discussions are based on results presented in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1991", Volume 1 - Results. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 68006 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In a continuing effort to condense the volume of material presented in this and related reports, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECO.

Plate 1 shows the ichthyoplankton sampling net being deployed on station in the PNPS discharge canal.

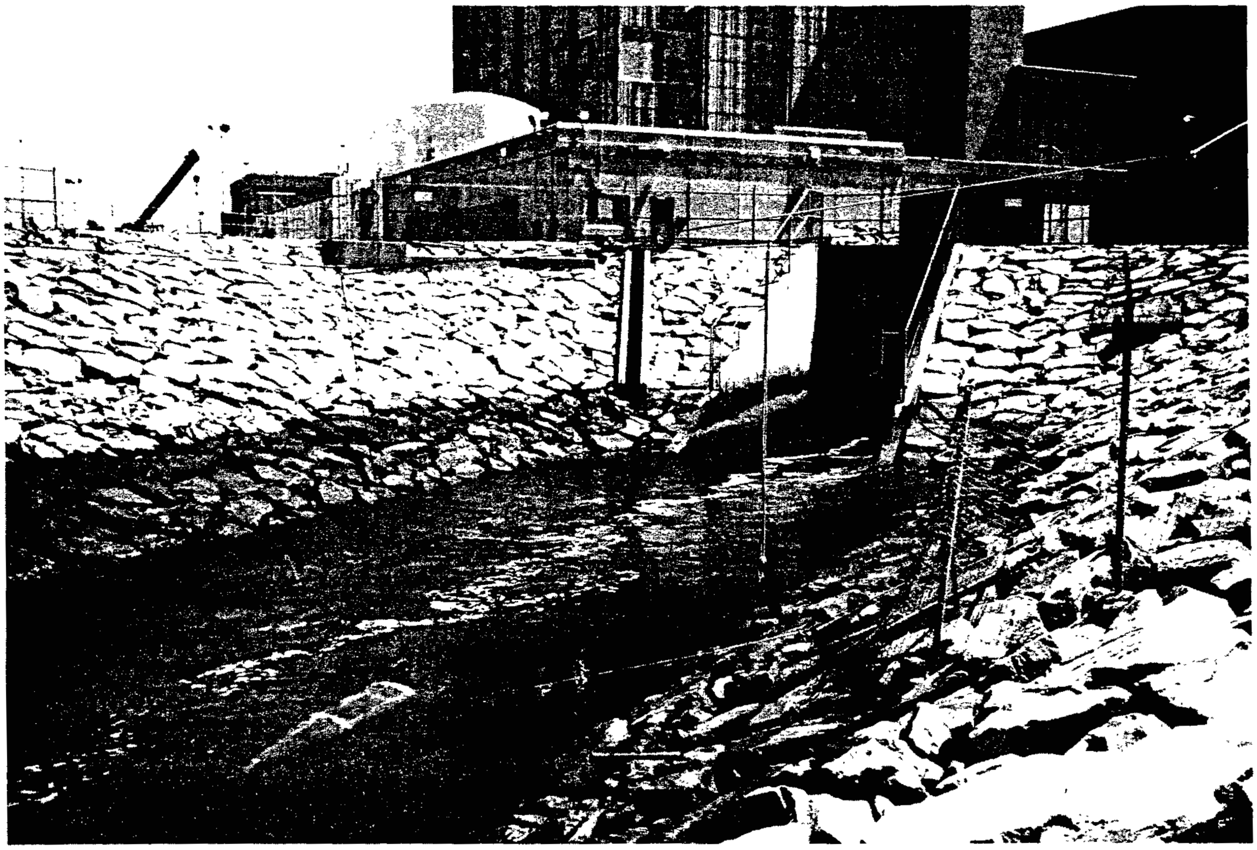

Plate 1. Plankton net streaming in the discharge canal at Pilgrim Station for the collection of fish eggs and larvae (lobster larvae are also recorded). A single, six-minute collection can contain several thousand eggs and larvae representing 20 or more species.

SECTION III

IMPACT PERSPECTIVE

A. Contingency Sampling Plan

Ichthyoplankton densities in the PNPS discharge canal meeting the "unusually abundant" criterion, defined as exceeding by 50% the highest mean density over three replicates recorded during the same month from 1975 through 1990, did not occur in 1991. This compares with no occurrences in 1989 or 1990, two occasions in 1988, no occurrences in 1987 or 1986, four in 1985, six in 1984, one in 1983, eight in 1982, seven in 1981, and twelve in 1980 (Table 1). No specific events were recorded prior to 1980 primarily because "unusually abundant" was not precisely defined early in the contingency plan.

In past years it was standard practice for BECO, in consultation with regulatory personnel, to authorize the collection of an additional set of triplicate entrainment samples following the recording of an unusually large density at PNPS. In most cases the additional sets were taken within two days of the original. In all but three cases when this occurred mean densities dropped back to levels within the range established over previous years, indicating that the "unusual" density probably reflected the occurrence of a high-density ichthyoplankton patch in the Rocky Point area rather than a more widespread phenomenon. In the three cases where high densities persisted (larval Atlantic menhaden, *Brevoortia tyrannus*, June 1981; larval rock gunnel, *Pholis gunnellus*, April 1982; larval

Table 1. Ichthyoplankton densities per 100 m^3 of water which reached the "unusually abundant"* level in PNPS entrainment samples, 1980-1991.

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
EGGS			
Brevoortia tyrannus	June	74.2 (1980)	6.2 (1978)
	September	1961.9 (1982)	1.4 (1979)
		1065.8 (1982)	" "
	October	37.8 (1980)	0.2 (1978)
Enchelyopus-*Urophycis* *Peprilus*	September	71.3 (1980)	30.1 (1979)
Urophycis spp.	September	152.8 (1980)	22.3 (1978)
Labrid-*Limanda* & labrid	July	12917.0 (1981)	8116.8 (1975)
Scomber scombrus	May	15261.3 (1985)	572.0 (1980)
		1457.6 (1985)	" "
LARVAE			
Brevoortia tyrannus	June	7.1 (1981)	4.2 (1980)
		495.9 (1981)	" "
		34.7 (1981)	" "
	October	11.7 (1980)	1.8 (1976)
	November	24.3 (1980)	3.2 (1978)
Enchelyopus cimbrius	August	204.6 (1983)	36.0 (1980)
Urophycis spp.	September	105.6 (1984)	22.3 (1981)
Tautoga onitis	August	21.6 (1984)	4.1 (1974)
	September	9.2 (1980)	4.8 (1975)
Tautogolabrus adspersus	June	624.5 (1981)	378.8 (1977)
	July	296.5 (1980)	138.5 (1974)
		2162.5 (1981)	296.5 (1980)
	September	20.3 (1980)	1.5 (1975)
Pholis gunnellus	February	19.6 (1984)	7.4 (1975)
		13.8 (1984)	" "
		47.5 (1985)	19.6 (1984)
	March	70.2 (1980)	36.9 (1975)
		210.5 (1984)	70.2 (1980)
		415.2 (1984)	" "
	April	74.0 (1982)	12.1 (1977)
		74.7 (1982)	" "
		34.0 (1982)	" "
		22.4 (1982)	" "
		23.5 (1982)	" "

Table 1 (continued).

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
LARVAE (continued)			
Ammodytes sp.	January	31.1 (1980)	13.5 (1975)
		104.4 (1985)	31.1 (1980)
Scomber scombrus	June	2700.0 (1981)	128.0 (1975)
Myoxocephalus spp.	February	79.2 (1988)	37.4 (1985)
	March	153.6 (1980)	97.0 (1975)
		308.3 (1988)	188.7 (1986)
	April	303.6 (1982)	53.1 (1981)

*"Unusually abundant" was defined as 50% greater than the previous high density observed during the same month 1975-1990.

rock gunnel, February 1985, additional entrainment sampling at about two-day intervals indicated that high densities continued for up to two weeks. Since no changes in PNPS operation occurred, it appeared in those situations that productivity was generally high relative to previous years.

B. Ichthyoplankton Entrainment - General

Entrainment of ichthyoplankton at PNPS represents a direct, negative environmental impact since fish eggs and larvae pass through the plant in large numbers each day and are subjected to elevated temperatures, mechanical forces, and periodic chlorination. When PNPS is not on line, increased temperature is not a factor but ichthyoplankton may still be subjected to mechanical forces and periodic chlorination when circulating seawater pumps operate. Although survival has been demonstrated for some species of fish eggs at PNPS such as the labrids (45%; Marine Research 1978, 1982) and among larvae at other power plants (0-100% initial survival depending on species and size; Ecological Analysts 1981), mortality is assumed to be 100% as a conservative approach to PNPS impact assessment.

To place fish egg and larval densities entrained at PNPS, expressed as numbers per 100 m^3 of water, in some perspective in relation to amounts of water utilized by PNPS, they were multiplied by maximum plant flow rates over each respective period of occurrence. This was completed for each of the numerically dominant species as well as total eggs and total larvae. Mean monthly densities were multiplied by 17,461.44, the full load flow capacity of PNPS in 100 m^3 units per 24-hour day, then by the number of days in each respective month they occurred. Values for each month in which a species or species group occurred were then summed to arrive at a seasonal entrainment value in each case (Figures 1 and 2). Among the eight numerically dominant groups, numbers of eggs entrained ranged from 2,079,658 for Atlantic menhaden to 628,704,386 for the labrid-yellowtail group (tautog, Tautoga onitis, cunner, Tautogolabrus adspersus, yellowtail flounder, Pleuronectes ferrugineus). Corresponding values among the eleven dominant larval species varied from a low of 2,046,481 for Atlantic herring (Clupea harengus) to a high of 108,184,098 for Atlantic mackerel (Scomber scombrus). For all eggs and all larvae combined, values amounted to 1,325,716,178 and 288,677,765, respectively. These numbers indicate the vast quantities of eggs and larvae which can be entrained by the circulating seawater system at PNPS during a year's time and are assumed to be lost to the local fish population.

C. Ichthyoplankton Entrainment - Specific

The effects of entrainment on populations of Atlantic menhaden, winter flounder (Pleuronectes americanus), pollock (Pollachius virens), cunner, rainbow smelt (Osmerus mordax), Atlantic silversides (Menidia menidia), and alewives (Alosa pseudoharengus) were assessed by Stone and Webster (1975) using flow rates for two units at Pilgrim Station. Using conservative

Number of Eggs Entrained - 1991

SPECIES AND PERIOD OF OCCURRENCE

Brevoortia tyrannus (June-November) atlantic menhaden
Enchelyopus-Urophycis-Peprilus (April-October) fourbeard rockling hake
Gadidae-Glyptocephalus (January-November) cod/haddock
Prionotus spp. (June-September) searobin
Labridae-Pleuronectes (May-October) cunner
Scomber scombrus (May-September) atlantic mackerel
Paralichthys-Scophthalmus (May-October) flounders windowpane
Hippoglossoides platessoides (April-June) american plaice

Total Eggs

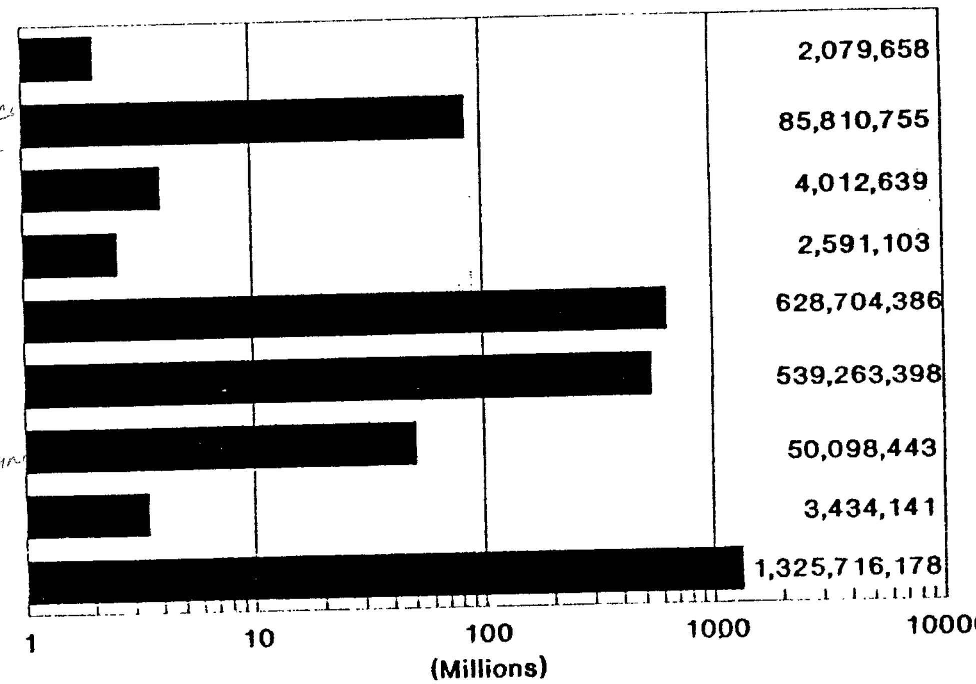

Figure 1. Numbers of eggs estimated to have been entrained by PNPS in 1991 had it operated at full pump flow by species or species group (dominants only) including all egg species combined. The period of occurrence observed in 1991 is also indicated.

SPECIES AND PERIOD OF OCCURRENCE

Clupea harengus (April-May, November-January)
Enchelyopus cimbrius (April-November)
Myoxocephalus spp. (February-June)
Liparis spp. (March-June)
Tautoga onitis (June-September)
Tautogolabrus adspersus (June-September)
Ulvaria subbifurcata (April-July)
Pholis gunnellus (January-May)
Ammodytes sp. (January-June)
Scomber scombrus (May-August)
Pleuronectes americanus (April-June)
Total Larvae

Number of Larvae Entrained - 1991

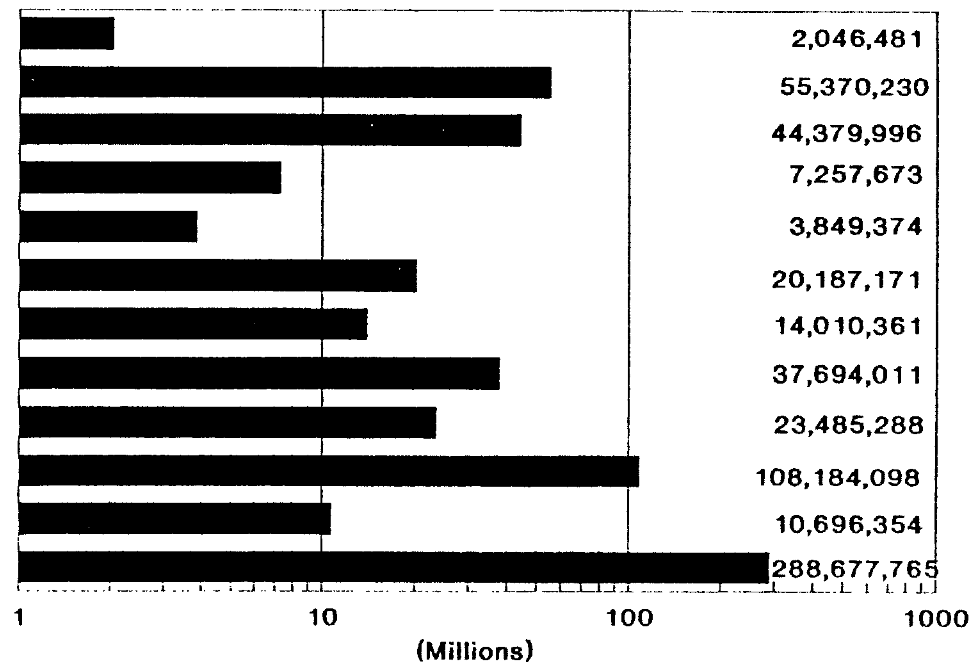

Figure 2. Numbers of larvae estimated to have been entrained by PNPS in 1991 had it operated at full pump flow for each dominant species including all larvae combined. The period of occurrence observed in 1991 is also indicated.

assumptions and ignoring density-dependent compensation among non-entrained ichthyoplankton, no appreciable adverse impact on indigenous populations was predicted to occur. Modeling studies conducted on five species of larval fish which appear to be more abundant in western Cape Cod Bay than in the remainder of the Bay (tautog; seasnail, Liparis spp.; radiated shanny, Ulvaria subbifurcata; sculpin, Myoxocephalus spp.; rock gunnel) suggested that the percentage of original larval production contributing to entrainment by PNPS Unit 1 was less than 1.0 (Marine Research 1978). For twelve additional categories of eggs and larvae (see Marine Research 1978) considered to be more widely distributed in Cape Cod Bay, percentages contributing to entrainment were smaller, the highest being 0.12% (labrid-Pleuronectes eggs).

If entrainment of ichthyoplankton at PNPS represented a significant source of mortality in western Cape Cod Bay, the losses might be reflected in finfish collections in the PNPS area. A review of indices of relative abundance for some species based on otter trawl and gill net sampling by Massachusetts Division of Marine Fisheries personnel (Lawton et al. 1990; V.J. Malkoski, personal communication) does not indicate any long-term steady declines among Atlantic herring, pollock, or tautog. Several species, on the other hand, have displayed recent declines in abundance. These include cunner, windowpane (Scophthalmus aquosus), yellowtail flounder, and winter flounder. In these cases, however, commercial landings, stock assessment research, and other monitoring studies indicate that these declines appear to be widespread, extending all along the Massachusetts coastline (MDMF 1985, Foster 1987, Howe et al. 1988, NOAA 1991, Marine Research 1991). Therefore, these specific declines appear to be the result of natural population variation probably coupled with overfishing.

D. Potential Pump Effects

PNPS was involved in a long-term outage which began in April 1986 and continued into 1989. During most of this period only one of two main circulating water system (CWS) pumps was operating (flow = 155,000 gpm, 9.78 m^3 per second, compared with 310,000 gpm or 19.56 m^3 per second, when the plant operates with two pumps). Beginning in late March 1987, intermittent use of a single circulating seawater pump made it basically unavailable for entrainment sampling, leaving only one or occasionally two Salt Service Water System (SSWS) pumps in service, each with a capacity of about 2500 gpm, or 0.16 m^3 per second. From May through early September 1987 sampling continued with only the SSWS pump(s) providing flow for entrainment sampling. This situation also occurred from April through late August 1984 although two SSWS pumps functioned throughout that period. During periods when sampling was completed with only SSWS pumps, ichthyoplankton densities appeared to be exceptionally low, particularly among larvae.

During recent years the apparent influence of different pump regimes on densities of ichthyoplankton have been compared over the months of April-August (see MRI 1988, 1989, 1990, 1991). Results strongly suggest that larvae and to a lesser extent eggs are entrained in direct proportion to plant pumping rates. With the 1991 data base in hand these analyses were continued to determine if the relationship between densities and pumping rates remained clear. The 1991 data set complicated the analysis because two CWS pumps were operating during April and August while only one operated during May, June, and July. This effectively reduced the data base for portions of the analysis to three months rather than four. To compare the response of ichthyoplankton to different pump regimes, densities per 100 m^3 of water were compared for single SSWS pump periods (1987), two SSWS pump periods (1984), single CWS pump periods (1986, 1988), and two CWS pump periods (1983, 1985, 1990). Statistical comparisons involving these data were initially restricted primarily to the May through August time frame when sampling was possible and the stated pump schedules were consistently maintained; the 1987 data set forced the exclusion of April from the statistical tests because no sampling occurred in April 1987 due to uncertainty concerning the pump use schedule at that time. The 1991 data set reduced statistical treatment to May through July. April and August data from all years analyzed were included in graphical analyses however. The 1991 data were simply divided, April and August averaged with two-CWS-pump years, May-July with one-CWS-pump years. Collections made between April and August 1989 did not fall clearly into any specific pump use category because the plant was returning to service, and CWS pump operation varied between one and two pumps. Only June and August

1989 were consistently sampled under one regime (all pumps in service).

When collections were first made in 1984 using the relatively low-volume SSWS pumps, an assumption was made that ichthyoplankton would continue to be sampled in proportion to its abundance in the Rocky Point area since larval fishes, especially the small ones, show little directional swimming ability and pelagic eggs certainly drift passively. Results reported in the 1986 annual PNPS report (Marine Research 1987) indicated that April-August 1984 larval entrainment collections (2 SSWS pumps only) were so low that local populations did not appear to be impacted in similar proportion by the SSWS pumps as by the CWS pumps. When 1987 larval data became available, the limited influence of the SSWS pumps became more apparent. May-August larval densities for 1987 when only one SSWS pump was used were exceptionally low each month, even when compared with 1984. Egg densities in 1987 ranked lowest over the 1983-1987 period only for August.

Mean densities per 100 m^3 of water for total eggs and total larvae, May-July 1983-1991 were examined using a nonparametric, single classification, Kruskal-Wallis test; data obtained on May 30, June 25, and August 19, 1987 were omitted because those samples were taken during brief periods of single CWS pump operation. For the Kruskal-Wallis test individual sampling dates were used. No significant difference was apparent among years for eggs ($p = 0.05$) but a very highly significant difference ($p < 0.001$) was found for larvae. Nonparametric multiple comparisons among years for larvae showed no significant difference (p = 0.05) among 1990, 1989, 1985, and 1983, years when the circulating water system operated at capacity for all or a portion of the season. No significant difference was noted among 1991, 1988, or 1986, years when one CWS pump was out of service, although this three-year group was significantly different from the all-pumps-operating group. However, the multiple range test was unable to separate 1985 (all pumps) from 1988 (one CWS pump), therefore a clear divisiion between the all-pumps and one-CWS-pump-O.S.S. group could not be shown statistically. Data sets from 1984 and 1987 clearly ranked below years when at least one CWS pump was in service. Statistically significant differences were noted between 1984 (two SSWS pumps and 1987 (one SSWS pump), both years also differing from all other years. The summed ranks as well as results of the multiple comparisons (indicated by vertical bars) were as follows:

May-July 1983-1991

RANK SUM EGGS	PUMPS	RANK SUM LARVAE	PUMPS
1989 - 2181	(ALL or 1 CWS O.O.S.)	1990 - 774	(ALL)
1985 - 1074	(ALL)	1989 - 746	(ALL or 1 CWS O.O.S.)
1988 - 863	(1 CWS O.O.S.)	1983 - 679	(ALL)
1983 - 680	(ALL)	1985 - 640	(ALL)
1990 - 394	(ALL)	1988 - 558	(1 CWS O.O.S.)
1991 - 333	(1 CWS O.O.S.)	1986 - 489	(1 CWS O.O.S.)
1987 - 302	(1 SSWS)	1991 - 475	(1 CWS O.O.S.)
1986 - 291	(1 CWS O.O.S.)	1984 - 518	(2 SSWS)
1984 - 152	(2 SSWS)	1987 - 189	(1 SSWS)
10.01 n.s.	Kruskal-Wallis Coefficient		37.11***

O.O.S. = Out Of Service

Figure 3 presents the monthly means averaged within pump operation categories for the April-August time frame. Data for May-August 1990 were averaged with the corresponding data from 1983 and 1985, the years of full operation. Data for April 1990 when only one CWS pump was in service were averaged with April 1986 and 1988. Similarly April and August 1991 were averaged with 1983 and 1985 when all pumps operated; May, June, July were averaged with 1986, 1988, and 1990, periods with one CWS pump. Larval densities separated distinctly, particularly when sampling occurred only with one or two salt service water pumps. Data for 1989 with mixed pump usage varied between the all and one CWS pump regimes but in a consistent manner. June and August with all pumps in service during each sampling period ranked above the other years. May and July with two of five and one of four dates with all pumps in service, respectively, showed monthly means which fell between the all and one CWS pump values. April, also having one of four dates with all pumps operating, fell below the one CWS pump category but well above the two SSWS pumps mean for that month.

The fact that the overall May-July data set for 1990 larvae ranked significantly higher than 1983 and 1985, the other full-operation years, suggests that larvae were relatively abundant during the late-spring and early-summer of 1990. Similarly, that 1989 ranked just below 1990 and was not found to be significantly different from 1990, in spite of the six dates when one CWS pump was out of service, suggests that in general larvae were relatively abundant during that period. In contrast, the low ranking of

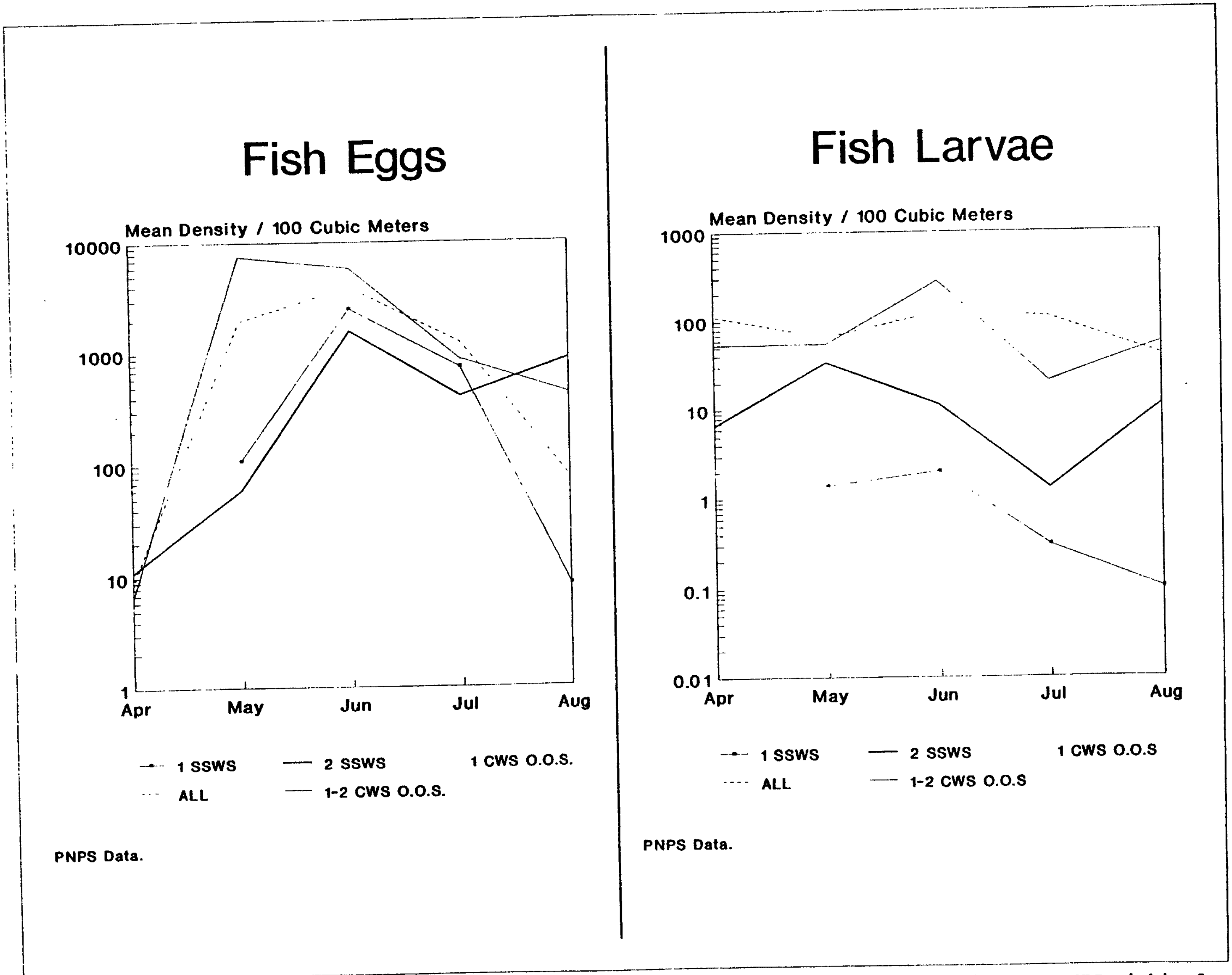

Figure 3. Mean monthly densities per 100 m³ of water for total eggs and total larvae entrained at PNPS within four pump operation categories during the April-August period of 1983-1991. See text for details.

larvae during the May-July 1991 period even among one CWS pump periods suggests larvae were relatively uncommon then; a review of the data indicated that July catch rates were particularly low.

The apparent reduced susceptibility of larvae to the SSWS pumps was further indicated by sampling on May 30, 1987 when collections were made while one CWS pump was placed into service for a short period. On May 28 no larvae were obtained while sampling under the influence of one SSWS pump. Two days later on May 30 a mean density of 132 larvae per 100 m^3 was obtained consisting of eight species. On June 4, again with only one SSWS pump operating, two larval species with a combined mean density of 2 per 100 m^3 of water were taken.

A comparison of the number of ichthyoplankton species recorded from May through July over the 1983-1991 period indicated that 1987 was clearly the lowest with 13 overall (22 with inclusion of the three dates when one CWS pump was in use); 1984 followed with 25. Numbers of species ranged from 29 (1986) to 34 (1989) during years when at least one CWS pump was in use. The low species count in 1987 was due primarily to a scarcity of larvae. Only six species of larvae were recorded over the May-July period of 1987 compared with 16 (1984) to 30 (1985, 1989) over the other years. Numbers of egg species were somewhat more consistent with 12 being taken in 1987 compared with 14 (1987 and 1988) to 20 (1991) during the other years. Including May 30 and June 25 1987 when a single CWS pump was in service brought the 1987 totals up to 14 species of eggs and 14 species of larvae.

The low densities of larvae in 1984 and the strikingly low densities in 1987 over the spring and early-summer period strongly suggest that ichthyoplankton populations near PNPS were not impacted in similar proportion by the SSWS pumps as by the main circulating seawater pumps. A sharp decline in larval densities occurred between 1984 and 1987 values, suggesting that dropping from two to one SSWS pump eliminated entrainment of many larvae. The intermediate values for 1986, 1988, and 1991 when one CWS pump was in service, ranking between 1984/1987 and 1983/1985/1990 suggests a direct relationship between pump flow and larval entrainment. Values for 1989 with variable pump operation further support this conclusion (Figure 3). Apparently the relatively low flow of the SSWS pumps has very limited influence on drawing larvae into the intake embayment area and subsequently through the PNPS condensers. These results could reflect mainly physical flow effects acting upon free-floating larvae or perhaps an active larval swimming ability, permitting an increasing number of them to avoid entrainment as pump capacity declines. For example, at some point water entrained by the PNPS intake separates from the prevailing Cape Cod Bay current and enters the intake area. The area over which the flow separation occurs is presumably more widespread and the action more forceful (the velocity higher) when two seawater pumps operate than when only one seawater pump operates, or even when one or two SSWS pumps operate. Passive larvae and eggs should be entrained in proportion to their abundance, but more active larvae may swim, to the extent of their ability, to remain within the Cape Cod Bay water mass. Also the more widespread the influence of a particular pumping rate, the higher the probability that high-density ichthyoplankton patches will be entrained. The role which vertical distribution plays may be of great importance as well, as the smaller pumps probably draw water over a more restricted vertical profile, one which may not coincide with the presence of many eggs and larvae.

Although no significant difference was detected among years for total eggs, years did rank in similar manner to the larvae. Notable exceptions occurred with 1988 (one CWS pump) which ranked third among the eggs and 1990 (2 CWS pumps) which ranked third among the fully operational years and fifth overall. The one SSWS and two SSWS pump years (1984 and 1987) again ranked low. As mentioned for larvae, the high ranking of 1989 among the eggs taken from May through July, when one CWS pump was out of service on six occasions, suggests that eggs were generally abundant during those months. Likewise the low ranking of 1986 eggs when only one CWS pump was out of service suggests egg densities were low that May-July period.

It is important to keep in mind that all comparisons based on different pump capacities were made without knowledge of ichthyoplankton populations around Rocky Point. The observed rankings could have been due entirely, or in part, to differences in production among the nine years, although that would appear to be an extraordinary coincidence given the well-defined relationship between ichthyoplankton densities and PNPS flow. Perhaps, on the contrary, the fact that densities ranked according to pump capacity in spite of high inter-year variability suggests how strong this relationship may be.

E. Lobster Larvae

The scarcity of larval lobsters (Homarus americanus) in PNPS entrainment samples is most interesting considering that, in 1980, 918 tons of legal-sized lobsters were landed in Plymouth County by commercial lobstermen with a value of four million dollars (Lawton et al. 1983). Among lobstermen working inshore waters, this increased to 1381 tons valued at $6.8 million in 1985 (Hoopes 1986) and 1485 tons valued at $7.5 million in 1986 (Hoopes 1987). Over the next four years, following a drop to 1262 tons in 1987, landings rose steadily to 1454 tons in 1990. Value of those landings varied from $7.1 to $8.1 million (Hoopes 1988, 1989, 1990, 1991). Neuston sampling conducted in the northwest sector of Cape Cod Bay (Lawton et al. 1983; Matthiessen and Scherer 1983) also indicated that larvae were not particularly abundant there. To support such a strong fishery it would appear young lobsters must arrive in the Plymouth area from other regions. Sampling around Rocky Point from 1974 through 1977 showed considerably more late-stage larvae than young larvae (Lawton et al. 1983). That, coupled with the prevailing counterclockwise Cape Cod Bay currents, suggests that larvae may arrive from the north. Sampling at the mouth of the Cape Cod Canal also suggests that large numbers of larvae enter Cape Cod Bay from Buzzards Bay and perhaps the Canal itself (Matthiessen and Scherer 1983; Matthiessen 1984). Regardless of source, larval lobsters appear to be especially uncommon in PNPS entrainment samples. This is supported by Lawton et al. (1983) who caught only eight larvae in twenty neuston tows near shore around Rocky Point in 1975. In addition to their apparent scarcity in near-shore waters, larval lobsters' neustonic habits may reduce the probability of their entrainment since they would contact the PNPS intake skimmer wall which might prevent some from passing to the condensers. Reduced intake flow during the extended outage period covering the 1986-1989 larval seasons no doubt lowered the probability of lobster entrainment even further.

SECTION IV

HIGHLIGHTS

1) Ichthyoplankton densities in the PNPS discharge canal meeting the "unusually abundant" criterion defined under the contingency sampling plan did not occur in 1991.

2) Total numbers of eggs and larvae which may have been entrained by PNPS in 1991 were estimated to range from 2.1 million for Atlantic menhaden eggs to 628.7 million for labrid-yellowtail eggs and from 2.0 million for Atlantic herring larvae to 108.2 million for Atlantic mackerel larvae.

3) Recent declines in cunner, windowpane, yellowtail flounder, and winter flounder appear to parallel more widespread declines and to be the result of natural population variation, probably coupled with overexploitation, rather than to be directly related to PNPS entrainment.

4) Analysis of entrainment data collected from April through August 1983-1991 strongly suggests that larvae and to a lesser extent eggs are entrained in direct proportion to plant pumping rates.

5) No larval lobsters were collected in PNPS entrainment samples in 1991. The low numbers taken in discharge samples remains surprising considering the strong commercial lobster fishery in the area.

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IMPINGEMENT OF ORGANISMS AT PILGRIM NUCLEAR POWER STATION

(January - December 1991)

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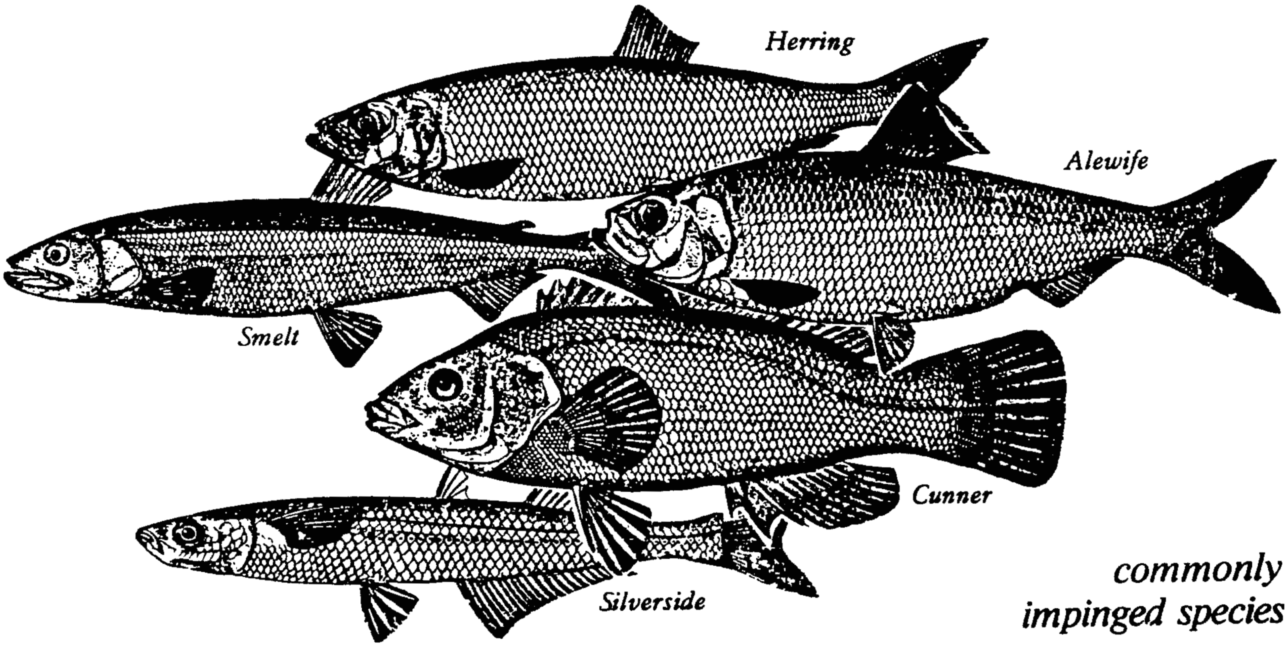

commonly
impinged species

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SECTION I

SUMMARY

Fish impingement rate averaged 6.27 fish/hour during the period January-December 1991, which is the highest rate since 1981 when there was also a large impingement incident. Atlantic herring (Clupea harengus harengus) accounted for 75.4% of the fishes collected. Atlantic silverside (Menidia menidia), Atlantic menhaden (Brevoortia tyrannus), and winter flounder (Pleuronectes americanus) accounted for 8.7, 3.6 and 2.1%, respectively, of the fishes impinged. The peak period was July 22-25 when an Atlantic herring impingement incident accounted for an estimated 4,200 of this species on the intake screens. Initial impingement survival for all fishes from static screen wash collections was approximately 57%, and from continuous screen washes 50%. Delayed mortality data was incomplete do to failure of the screenwash survival pools, lost fishes or sampling in the screenhouse during portions of 1991.

At 100% yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated impingement was 54,925 fishes (784 lbs.). The PNPS capacity factor was 58% during 1991.

The collection rate (no./hr.) for all invertebrates captured from January-December 1991 was 1.40+. Jellyfish and blue mussels (undetermined numbers), common starfish (Asterias forbesi) and sevenspine bay shrimp (Crangon septemspinosa) were most numerous, the latter species accounting for approximately 25.4 and 22.3%, respectively, of the enumerated invertebrates impinged. Mixed species of algae collected on intake screens amounted to 2,880 pounds.

SECTION 2

INTRODUCTION

Pilgrim Nuclear Power Station (lat. 41°56' N, long. 70°34' W) is located on the northwestern shore of Cape Cod Bay (Figure 1) with a licensed capacity of 670 MWe. The unit has two circulating water pumps with a capacity of approximately 345 cfs each and five service water pumps with a combined capacity of 23 cfs. Water is drawn under a skimmer wall, through vertical bar racks spaced approximately 3 inches on center, and finally through vertical travelling water screens of 3/8 inch wire mesh (Figure 2). There are two travelling water screens for each circulating water pump.

This document is a report pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (USEPA) and No. 359 (Mass. DWPC) for Pilgrim Nuclear Power Station, Unit I. The report describes impingement of organisms and survival of fishes carried onto the vertical travelling water screens at Unit I. It presents analysis of the relationships among impingement, environmental factors, and plant operational variables.

The report is based on data collected from screen wash samples during January-December 1991.

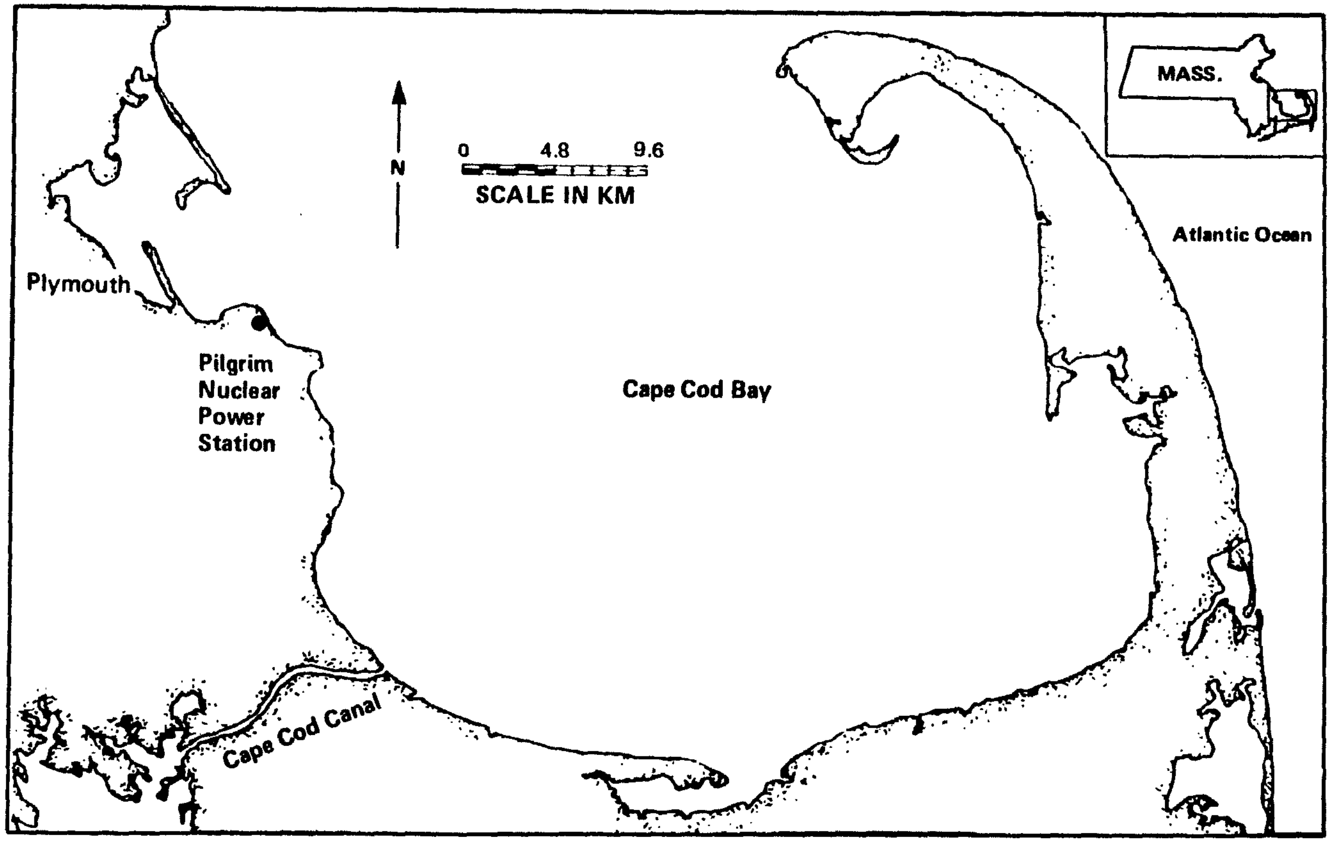

Figure 1. Location of Pilgrim Nuclear Power Station.

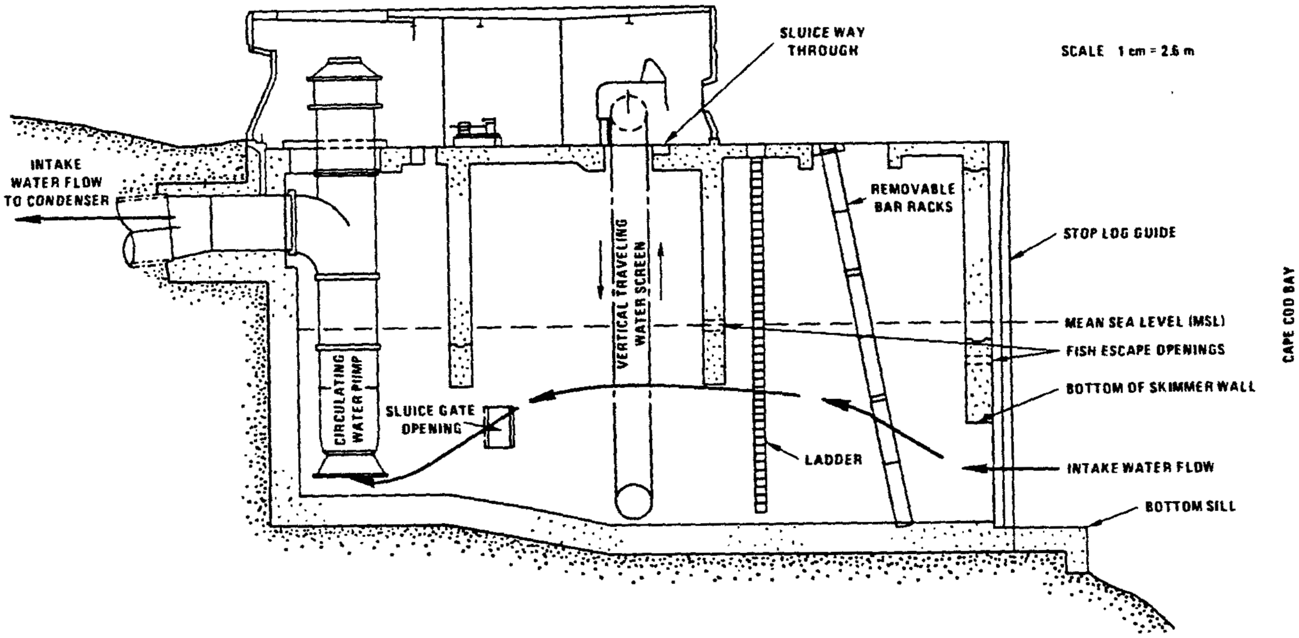

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1991 to provide data for evaluating the magnitude of marine biota impingement. The total weekly collection time was 24 hours (three separate 8-hour periods: morning, afternoon and night). Two collections represented dark period sampling and one represented light period sampling. At the beginning of each collection period, all four travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and it collected impinged biota shortly after being washed off the screens. A second trap was designed and used for sampling, in conjunction with sluiceway survival studies, consisting of a section of half 18" corrugated metal pipe with 3/16-inch nylon, delta mesh netting attached. Impinged biota sampled by this trap were collected at the end of a 300' sluiceway where initial, one-hour and latent (56-hour) fish survival were determined for static (8-hour) and continuous screenwash cycles. Plates 1 and 2 provide views of the beginning and end of this sluiceway structure which was constructed in 1979.

Variables recorded for organisms were total numbers, and individual total lengths (mm) and weights (gms) for up to 20 specimens of each species. A random sample of 20 fish or invertebrates was taken whenever the total number for a species exceeded 20; if the total collection for a species was less than 20, all were measured and weighed. Field work was conducted by Marine Research, Inc.

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at the time of collections. The collection rate (#/hour) was calculated as number of organisms impinged per collecting period divided by the total number of hours in that collecting period. Beginning in 1990, if all four intake screens are not washed for a collecting period then the number of fishes collected is increased by a proportional factor to account for the unwashed screens, as requested by the Pilgrim Administrative-Technical Committee. Common and scientific names in this report follow the American Fisheries Society (1988, 1989 and 1991) or other accepted authority when appropriate.

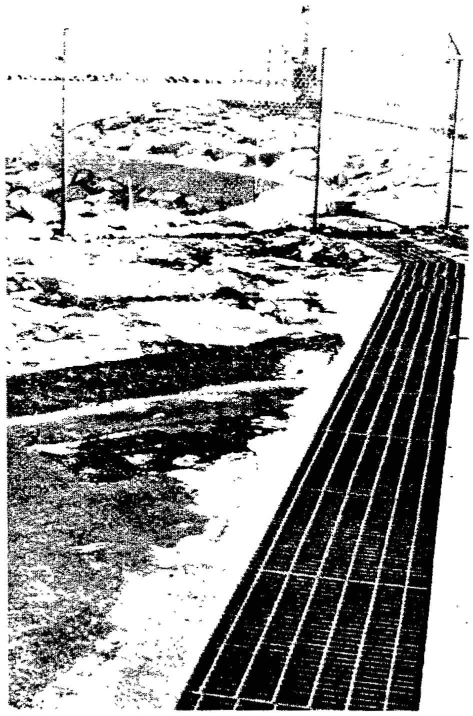

Plate 1. The 300 foot long Pilgrim Station, concrete screenwash sluiceway is molded from 18" corrugated metal pipe, and meanders over breakwater rip rap.

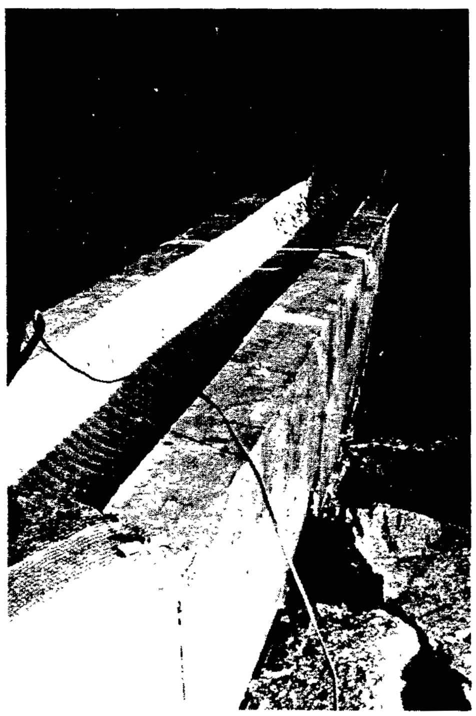

Plate 2. Fish survival testing is done at the end of the sluiceway where it discharges to ambient temperature intake waters.

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 501.25+ collection hours, 3,145 fishes of 39 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - December 1991. The collection rate was 6.27 fish/hour. This annual impingement rate is the highest since 1981 because of a large impingement incident of over 4,000 Atlantic herring (*Clupea harengus harengus*) from July 22-25. Atlantic herring was the most abundant species in 1991, accounting for 75.4% of all fishes collected (Table 2). Atlantic silverside (*Menidia menidia*), Atlantic menhaden (*Brevoortia tyrannus*) and winter flounder (*Pleuronectes americanus*) accounted for 8.7, 3.6 and 2.1% of the total number of fishes collected and identified to lowest taxon.

Atlantic herring occurred most predominantly in monthly samples from June and July. Hourly collection rates per month for them ranged from 0 to 24.44. Atlantic herring impinged in June and July accounted for 98% of all this species captured in impingement collections from January-December 1991. They averaged 81 mm total length and 3 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. It is somewhat unusual for them to be the dominant fish in the annual impingement catch, the only other years in which they were being 1986 and 1976. A review of historical data shows the juveniles of this species to be impinged in greatest numbers during the spring/summer period when they were well represented in 1991, being most prevalent in late July of that year. Some other relatively abundant species impinged at Pilgrim Station over the past 10 years are also documented in Table 3.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January–December 1991

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Atlantic herring			12	7	2	167	2,169				2	11	2,370
Atlantic silverside	9	24	55	114	1	2					36	34	275
Atlantic menhaden								4	61	4	11	33	113
Winter flounder	3	4	11	2	3		3	3	4	2	26	6	67
Grubby	9	8	8	3	1		2	2	2		9	2	46
Rainbow smelt	2	1		4	3			1	3	11	3	13	41
Blueback herring			8	5			2				2	14	31
Alewife	4		2	6				1	2	1	5	3	24
Cunner	4	1		2	10		1	2	2	1			23
Scup								4	7	7			18
Tautog				1						6	5	6	18
Atlantic tomcod	5			1	1						4	5	16
Northern puffer								1	8	6			15
Windowpane	2		6	1	2								11
Little skate					6	1				1			8
Striped killifish											6	1	7
Red hake	1			3	2								6
Rock gunnel			4	2									6
Lumpfish	3										1	1	5
Northern searobin					4								4
Pollock					4								4
Bay anchovy							1			2			3
Butterfish								2	1				3
Northern pipefish			3										3
Sand lance sp.					2					1			3
Silver hake					1		2						3
Striped searobin			3										3
White perch										2	1		3
Atlantic cod											2		2
Black sea bass									1	1			2
Fourspot flounder						2							2
Radiated shanny				1								1	2
Threespine stickleback			1									1	2
Hog choker							1						1
Mummichog											1		1
Northern kingfish									1				1
Shorthorn sculpin									1				1
Smooth dogfish	1												1
Spiny dogfish									1				1
TOTALS	43	38	113	152	42	172	2,181	20	94	44	115	131	3,145
Collection Time (hrs.)	74	67	74	65	128	21+	88.75+	111	69	87.50	59	86	501.25+
Collection Rate (#/hr.)	0.58	0.57	1.53	2.34	0.33	8.19	24.57	0.18	1.36	0.50	1.95	1.52	6.27

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-December 1991

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Atlantic herring	2,370	38-333	81	0.1-166	3	75.4
Atlantic silverside	275	72-143	105	2-14	5	8.7
Atlantic menhaden	113	52-131	78	1-19	4	3.6
Winter flounder	67	46-335	104	1-152	15	2.1
Grubby	46	40-110	80	1-20	6	1.5
Rainbow smelt	41	68-185	112	1-36	8	1.3
Blueback herring	31	75-126	91	2-15	5	1.0
Alewife	24	73-138	98	3-18	7	0.8
Cunner	23	45-176	120	2-92	41	0.7
Scup	18	40-88	60	1-9	4	0.6
Tautog	18	55-160	75	2-63	9	0.6
Atlantic tomcod	16	89-235	152	4-85	34	0.5
Northern puffer	15	42-135	78	2-60	19	0.5
Windowpane	11	40-104	77	1-13	5	0.3
Little skate	8	470-511	497	650-905	772	0.2
Striped killifish	7	76-96	87	5-11	8	0.2
Red hake	6	89-181	140	4-34	18	0.2
Rock gunnel	6	70-196	124	1-21	7	0.2
Lumpfish	5	40-83	56	2-11	4	0.1
Northern searobin	4	240-255	248	139-149	144	0.1
Pollock	4	51-70	60	1-3	2	0.1
Bay anchovy	3	53-85	73	1-5	3	0.1
Butterfish	3	37-42	40	1	1	0.1
Northern pipefish	3	140-141	140	1	1	0.1
Sand lance sp.	3	140-202	161	10-19	13	0.1
Silver hake	3	93-160	138	6-22	17	0.1
Striped searobin	3	96	96	8	8	0.1
White perch	3	60-108	83	3-14	8	0.1
Atlantic cod	2	72-89	81	3-6	5	0.06
Black sea bass	2	60-73	67	3-5	4	0.06
Fourspot flounder	2	318	318	-	-	0.06
Radiated shanny	2	85-108	97	5-10	8	0.06
Threespine stickleback	2	39-63	51	1-2	2	0.06
Hog choker	1	126	126	44	44	0.03
Mummichog	1	66	66	4	4	0.03
Northern kingfish	1	200	200	85	85	0.03
Shorthorn sculpin	1	86	86	8	8	0.03
Smooth dogfish	1	781	781	-	-	0.03
Spiny dogfish	1	915	915	-	-	0.03

Table 3. Annual Impingement Collections (1982-1991) For the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1991

Species	1982	1983	1984*	1985	1986	1987**	1988***	1989	1990	1991	Totals
	Number of Impinged Fishes Collected From January - December										
Atlantic herring	9	2	0	2	346	1	2	16	35	2,370	2,783
Atlantic silverside	133	97	22	174	44	27	35	120	457	275	1,384
Atlantic menhaden	15	33	2	76	113	0	4	82	345	113	783
Winter flounder	27	20	5	39	76	10	11	42	31	67	328
Grubby	13	38	15	36	30	5	5	29	59	46	276
Rainbow smelt	60	57	5	8	278	41	11	39	38	41	578
Blueback herring	24	59	5	17	5	1	2	15	103	31	262
Alewife	25	8	12	37	25	4	8	8	131	24	282
Cunner	63	16	6	27	26	14	2	17	22	23	216
Scup	8	1	0	6	0	0	0	5	62	18	100
Totals	377	331	72	422	943	103	80	373	1,283	3,008	6,992
Collection Time (hrs)	687	763	1,042	465	806	527	525	618	919.5	501.25+	6,853.75+
Collection Rate (#/hr)	0.46	0.42	0.07	0.86	1.14	0.17	0.15	0.58	1.55	6.00	1.02

*No CWS pumps were in operation 29 March - August 1984.
**No CWS pumps were in operation 18 February - 8 September 1987.
***No CWS pumps were in operation 14 April - 5 June 1988.

Atlantic menhaden dominated the September impingement collections and have been most prevalent in the fall period, ranking third in 1986 and second in 1989/1990. It has been unusual for them to rank very highly in impingement (Table 3), and their increased abundance recently on PNPS intake screens may reflect a natural population resurgence.

Atlantic silverside occurred predominantly in March/April when 61% of them were sampled, reflecting this species historical nature for maximum impingement in the early springtime. It has been one of the most impinged fish, dominating the annual catch in 7 out of the last ten years.

Winter flounder were relatively prevalent in March and November samples, possibly indicative of this species seasonal inshore and offshore movements, respectively. It has been one of the more commonly impinged fish over the years.

Grubby (<u>Myoxocephalus</u> <u>aneus</u>) (1.5% of the catch) were impinged most in the winter and have historically been collected in relatively low numbers, although its year-round presence in the Pilgrim Station area is apparent. Monthly intake water temperatures and impingement rates for the five dominant species in 1991 are illustrated in Figure 3.

There was a large, fish impingement incident (20 fish or greater/hr.) at Pilgrim Station in 1991 from July 22-25 when a rate of 52.29 fish/hr. (Atlantic herring) was recorded over this period with one circulating water pump in operation. Approximately 4,200 juvenile (80-85 mm TL) Atlantic herring were estimated impinged and killed during the incident. Regulatory authorities were notified and kept informed until the incident was over. All previous large fish impingment mortalities (>1,000 fish) have occurred while

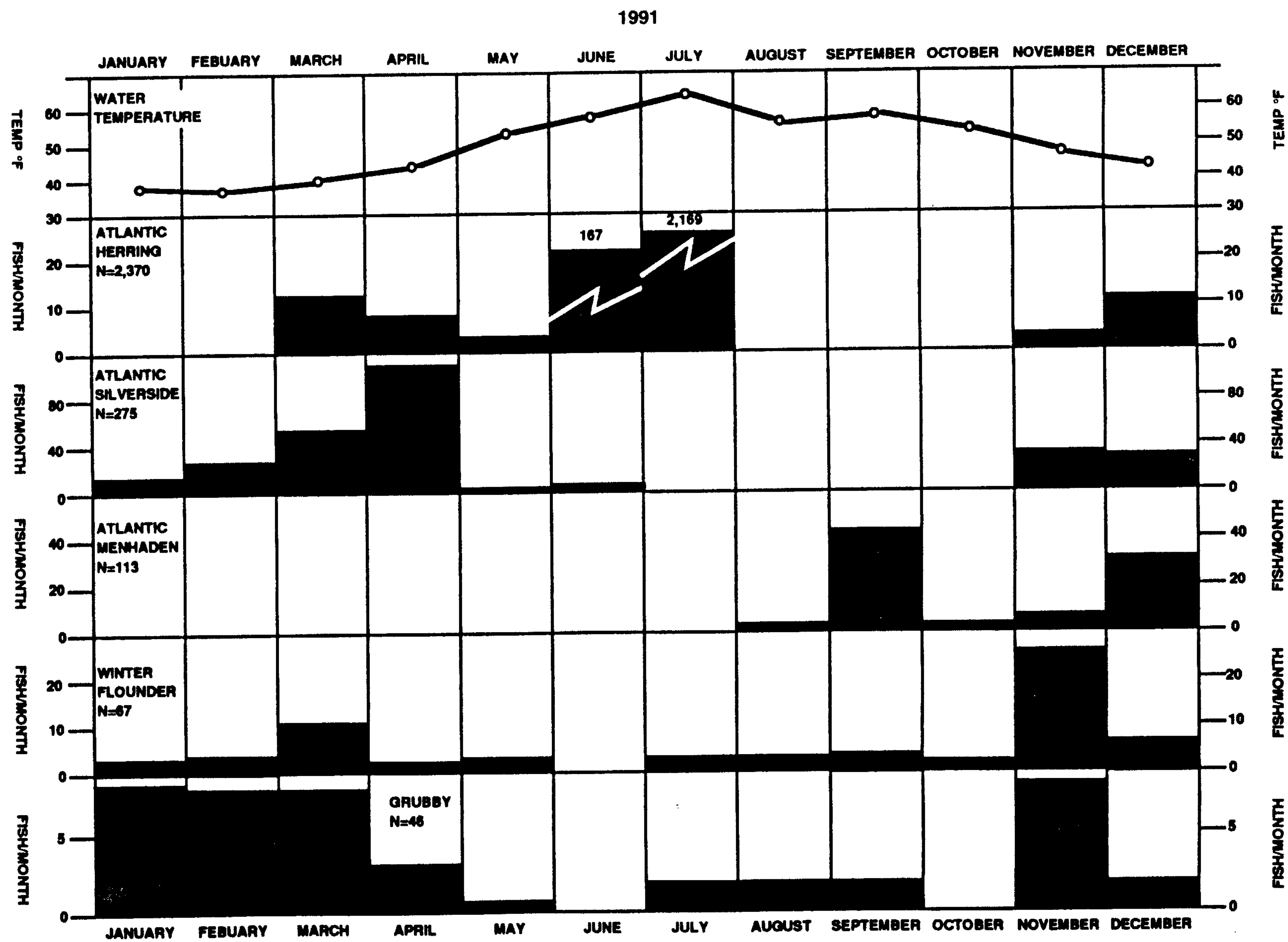

Figure 3. Trends of Intake Water Temperature, and Number of Fish Captured by Month from Pilgrim Station Intake Screens for the Five Most Abundant Speices Collected, January-December 1991.

both circulating water pumps were operating. Eleven large fish incidents have been documented since Pilgrim operation commenced in 1972, and most (7) have involved impingement as the causative agent (Table 4). However, at least in two of these the possibility of pathological influence was implicated as indirectly contributing to the mortalities. They were the Atlantic herring (Clupea harengus harengus) (tubular necrosis) and rainbow smelt (Osmerus mordax) (piscine erythrocytic necrosis) impingement incidents in 1976 and 1978, respectively.

Fish impingement rate at Pilgrim Station has been shown to be significantly related to the number of circulating water pumps operating (Lawton, Anderson et al, 1984b). Reduced water pumping capacity has lowered total impingement, particularly during the April-mid-August 1984 and portions of the mid-February-August 1987 periods when no circulating water pumps were operating for extended time frames. The significance of this relationship is supported by the fact that total fish impingement and rate of fish impingement were several times lower in 1984 and 1988 (low-pump year) than in 1985, 1986 and 1989 - 1991, despite a greater number of collecting hours in 1984 and an average number of hours in 1988. In 1987, far fewer collecting hours were possible when both circulating pumps were off than in these other years which limits comparisons to them. However, total fish impingement rates in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1991 when at least one circulating pump was always in operation. Figure 4 illustrates the relationship between fish impingement rate and number of circulating pumps operating which demonstrates, for the most part, the rate reduction effect of no pumps vs. 1 or 2 pumps.

Projected fish impingement rates were calculated assuming 100% operation of Pilgrim Nuclear Power Station, under conditions at the times of impingement,

Table 4. Approximate Number and Cause for Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1991

Date	Species	Number	Cause
April 9-19, 1973	Atlantic Menhaden	43,000	Gas Bubble Disease
August/September, 1973	Clupeids	1,600	Impingement
April 2-15, 1975	Atlantic Menhaden	5,000	Gas Bubble Disease
August 2, 1975	Atlantic Menhaden	3,000	Thermal Stress
August 5, 1976	Alewife	1,900	Impingement
November 23-28, 1976	Atlantic Herring	10,200	Impingement
August 21-25, 1978	Clupeids	2,300	Thermal Stress
December 11-29, 1978	Rainbow Smelt	6,200	Impingement
March/April, 1979	Atlantic Silverside	1,100	Impingement
September 23-24, 1981	Atlantic Silverside	6,000	Impingement
July 22-25, 1991	Atlantic Herring	4,200	Impingement

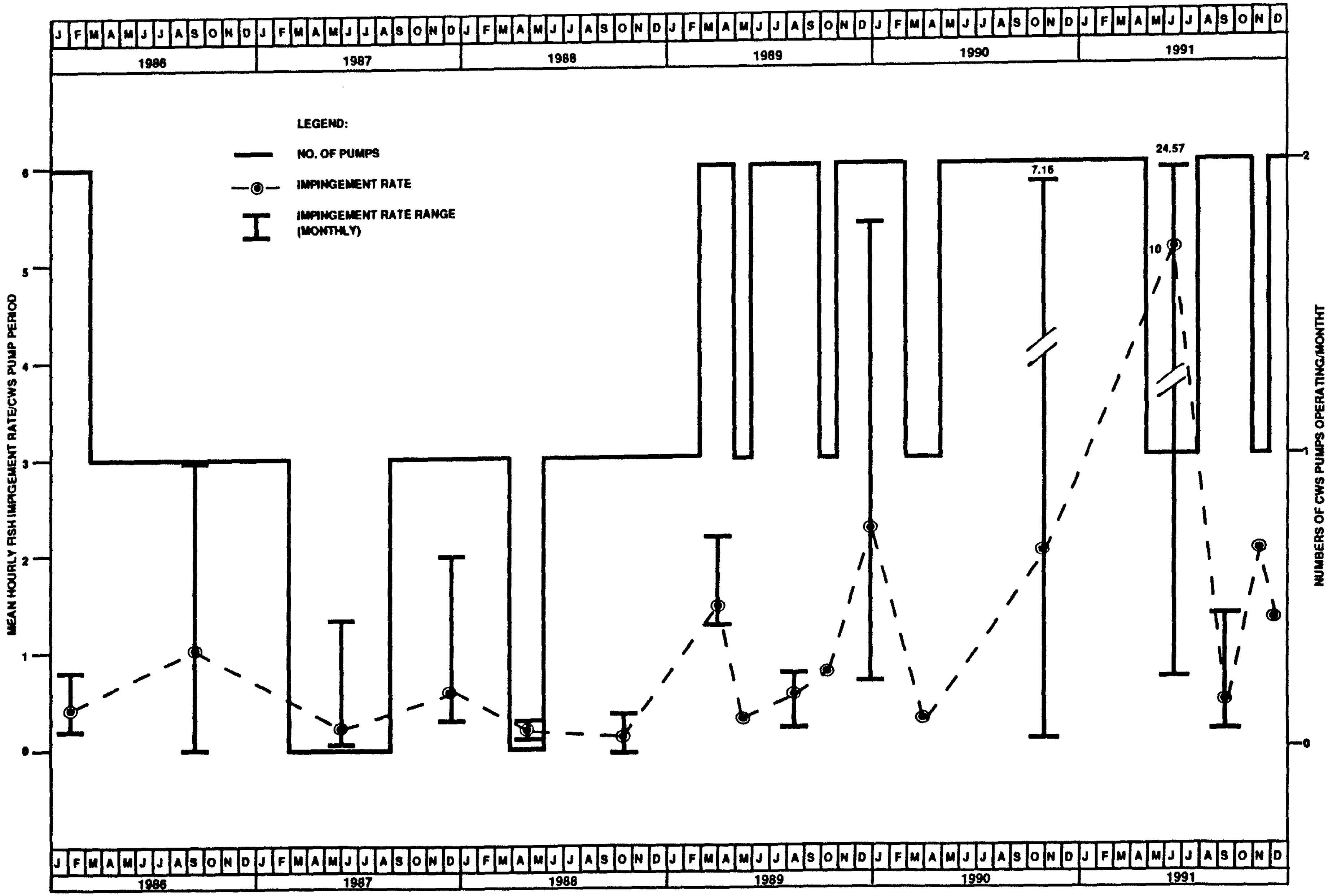

Figure 4. Relationship of Pilgrim Station Circulating Water System (CWS) Pumps' Operation (Pump Flow) to Fish Impingement Rate for the Period 1986-1991.

during the period January-December 1991. Table 5 presents hourly, daily and yearly impingement rates for each species captured (rates are rounded to significant figures). For all fishes combined the respective rates are 6.27, 150.48, and 54,925. The yearly rate of 54,925 fishes impinged is 288% of the 19-year (1973-1991) mean annual projection of 19,074 fishes (Table 6). This is the highest, yearly fish impingement rate since 1981 and greatly exceeds the historical annual average as have other years in which large impingement mortalities inflated yearly projections. The relatively low rates of 1984, 1987 and 1988 offset these high impingement incident years and may be attributed to very low circulating water pump operation during outages, as previously discussed. Population variances of the dominant species can also influence impingement levels in any year.

Over the 19-year period (1973-1991) it has been operating, Pilgrim Station has had a mean annual impingement rate of 2.18 fishes/hr., ranging from 0.13 (1984) to 10.02 (1981) (Table 6). Anderson et al. (1975) documented higher annual impingements at seven other northeast power plants in the early 1970's. Maine Yankee Atomic Power Company (1978), at their Nuclear Generating Station, had a mean impingement rate of approximately 58 fishes/hr. from late 1972 - late 1977. Stupka and Sharma (1977) showed annual impingement rates at numerous power plant locations for dominant species, and compared to these rates at Pilgrim Station were lower than at most other sites. However, in terms of the number of fish species impinged, Pilgrim Station displays a far greater variety than other power plants in the Gulf of Maine area (Bridges and Anderson, 1984a), perhaps because of its proximity to the boreal-temperate zoogeographical zone presented to marine biota by Cape Cod.

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1991. Assuming 100% Operation of Pilgrim Unit 1*

Species	Rate/Hr.	Rate/Day	Rate/January-December 1991*	Dominant Months Of Occurrence
Atlantic herring	4.73	113.48	41,419	July
Atlantic silverside	0.55	13.17	4,806	April
Atlantic menhaden	0.23	5.41	1,975	September
Winter flounder	0.13	3.21	1,171	November
Grubby	0.09	2.20	804	January&November
Rainbow smelt	0.08	1.96	717	December
Blueback herring	0.06	1.48	542	December
Alewife	0.05	1.15	419	April
Cunner	0.05	1.10	402	May
Scup	0.04	0.86	315	September&October
Tautog	0.04	0.86	315	October&December
Atlantic tomcod	0.03	0.77	280	December&January
Northern puffer	0.03	0.72	262	September
Windowpane	0.01	0.53	192	March
Little skate	0.02	0.38	140	May
Striped killifish	0.01	0.34	122	November
Red hake	0.01	0.29	105	April
Rock gunnel	0.01	0.29	105	March
Lumpfish	0.01	0.24	87	January
Northern searobin	0.01	0.19	70	May
Pollock	0.01	0.19	70	May
Bay anchovy	0.01	0.14	52	October
Butterfish	0.01	0.14	52	August
Northern pipefish	0.01	0.14	52	March
Sand lance sp.	0.01	0.14	52	May
Silver hake	0.01	0.14	52	July
Striped searobin	0.01	0.14	52	March
White perch	0.01	0.14	52	October
Atlantic cod	0.004	0.10	35	November
Black sea bass	0.004	0.10	35	September&October
Fourspot flounder	0.004	0.10	35	June
Radiated shanny	0.004	0.10	35	April&December
Threespine stickleback	0.004	0.10	35	March&December
Hog choker	0.002	0.05	17	September
Mummichog	0.002	0.05	17	November
Northern kingfish	0.002	0.05	17	September
Shorthorn sculpin	0.002	0.05	17	September
Smooth dogfish	0.002	0.05	17	January
Spiny dogfish	0.002	0.05	17	September
Totals	6.27	150.48	54,925	

*Rates have been rounded to significant figures.

Table 6. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During 1973-1991, Assuming 100% Operation of Pilgrim Unit 1*

Year	Rate/Hr.	Rate/Day	Rate/Year	Dominant Species (Rate/Year)
1973	1.41	33.89	12,371	Clupeids** (7,473)
1974	0.58	13.85	5,056	Clupeids** (4,542)
1975	0.19	4.54	1,659	Atlantic silverside (702)
1976	6.67	160.17	58,461	Atlantic herring (45,065)
1977	1.06	25.44	9,286	Atlantic silverside (2,735)
1978	4.04	97.03	35,416	Rainbow smelt (29,357)
1979	3.24	77.69	28,280	Atlantic silverside (20,733)
1980	0.66	15.78	5,769	Cunner (1,683)
1981	10.02	240.42	87,752	Atlantic silverside (83,346)
1982	0.93	22.39	8,173	Atlantic silverside (1,696)
1983	0.57	13.65	4,983	Atlantic silverside (1,114)
1984+	0.13	3.13	1,143	Atlantic silverside (185)
1985	1.14	27.46	10,022	Atlantic silverside (3,278)
1986	1.26	30.34	11,075	Atlantic herring (3,760)
1987++	0.28	6.74	2,460	Rainbow smelt (682)
1988+++	0.27	6.48	2,372	Atlantic silverside (586)
1989	0.80	19.30	7,045	Atlantic silverside (1,701)
1990	1.70	40.74	14,872	Atlantic silverside (4,354)
1991	6.27	150.48	54,925	Atlantic herring (41,419)
Means	2.18	52.26	19,074	

*Rates have been rounded to significant figures.

**Herrings (clupeids) identified as a general category in 1973 and 1974 consisted of alewife, blueback herring and Atlantic menhaden.

+No CWS pumps were in operation 29 March - 13 August 1984.

++No CWS pumps were in operation 18 February - 8 September 1987.

+++No CWS pumps were in operation 14 April - 5 June 1988.

Monthly intake water temperatures recorded during impingement collections at Pilgrim Station were generally warmer the first half and colder the second half of 1991 compared to the mean monthly temperatures for the 10-year interval 1982-1991 (Table 7). The May and June water temperatures were higher, and August and September lower than any previous monthly highs for these months in that 10-year period.

Overall, 1982/1983/1985/1986/1990 displayed relatively warm water temperatures, 1984/1987/1989/1991 were average years, and 1988 was a cold water year. Pilgrim Station intake temperatures approximate ambient water temperatures. A relatively even distribution of both dominant warmer water (i.e., cunner , scup and Atlantic menhaden) and cold water (i.e., winter flounder, grubby and rainbow smelt) species appeared in impingement collections during 1991.

4.2 Invertebrates

In 501.25+ collection hours, 704+ invertebrates of 19 species (Table 8) were recorded from Pilgrim Station intake screens from January-December 1991. The annual collection rate was 1.40+ invertebrates/hour. Jellyfish dominated the catch, being captured in July and August in numbers too numerous to count. Blue mussels were impinged in May in undetermined numbers. Common starfish (*Asterias forbesi*) and sevenspine bay shrimp (*Crangon septemspinosa*) represented 25.4 and 22.3% respectively, of the total invertebrates enumerated. Unlike the fishes, the 1987 and 1988 invertebrate impingement rates were comparable to 1985, 1986, and 1989 - 1991 despite relatively low circulating water pump capacity available in 1987 and 1988. An unusual occurrence was the collection of so many blue mussels during 1986-1989.

Table 7. Monthly Means of of Intake Temperature (°F) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1982-1991

Month	Year										(X)
	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1982-1991
January	37.56	38.45	37.85	36.80	38.42	35.97	35.61	33.55	38.88	*	37.03
February	36.70	38.15	42.97	36.00	38.71	34.98	33.40	36.08	37.05	*	37.12
March	39.72	37.87	38.43	36.20	40.70	37.18	37.84	37.62	40.25	*	38.46
April	44.46	46.63	41.37	41.30	*	44.98	41.85	*	43.14	43.60	44.23
May	53.79	50.86	48.70	48.79	*	48.84	50.55	*	47.26	49.73	49.81
June	60.09	53.63	57.38	50.21	56.68	56.11	56.31	*	57.54	55.10	55.89
July	61.67	61.24	61.57	52.83	63.00	61.51	58.96	67.00	59.44	55.98	60.32
August	58.49	64.71	59.80	58.75	*	63.29	63.44	64.62	61.46	60.23	61.64
September	58.63	63.35	58.62	56.86	58.21	58.26	63.74	60.91	61.06	59.04	59.88
October	52.00	55.13	53.92	52.31	52.73	58.58	57.75	55.88	55.38	55.60	54.93
November	47.88	47.88	45.60	47.17	47.49	52.23	52.01	45.71	49.64	50.36	48.59
December	41.74	42.86	35.58	38.90	41.30	44.00	42.22	42.30	41.43	44.55	41.50
Mean											49.12

* Temperatures were incompletely recorded during PNPS outages in these months.

Table 8. Monthy Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-December 1991

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.
Jellyfish							*	*					*
Common starfish	25	3	30	14	7	7	40	20	5	16	9	3	179
Sevenspine bay shrimp	29	42	43	21	2						3	17	157
Rock crab	6	4	6	13	3	4	23	14	1	3	7	3	87
Green crab		1		7	4	1	16	15	1	9	10	1	65
American lobster			3	11	2	5	4	9	9	7	4		54
Lady crab			2	1					4	19	19		45
Blue mussel	3		2	6	*	16	6					3	36+
Longfin squid							1	6	16	6		2	31
Horseshoe crab				1	10	10				1			22
Isopoda	1	1			7						1		10
Nereis sp.		2	5										7
Green seaurchin		1	1			1	1						4
Longwrist hermit				2									2
Artic Lyre Crab											1		1
Cirripedia		1											1
Loligo sp.											1		1
Nemertea		1											1
Pagurus sp.			1										1
TOTALS	64	56	93	76	35+	44	91+	64+	36	61	55	29	704+
Collection Time (hrs.)	74	67	74	65	128	21+	88.75+	111	69	87.50	59	86	501.25+
Collection Rate (#/hr.)	0.86	0.84	1.26	1.17	0.27+	2.09	1.03+	0.58+	0.52	0.70	0.93	0.34	1.40+

* Undetermined numbers

This could be an effect of the Pilgrim Station outage during the late 1980s (reduced power level in 1989) which precluded the use of regular thermal backwashes for macrofouling control, and the migratory/adhesive abilities of mussels. In 1990 and 1991 several thermal backwashes were performed and blue mussel impingement was relatively minor for most of those years.

Common starfish were the third most abundant invertebrates impinged, peaking in July. Generally, their concurrent abundance with mussels reflects the starfish's predatory relationship with them in the intake. Sevenspine bay shrimp impingement peaked in January - March. The greatest collections of rock crab (Cancer irroratus), the fifth most impinged invertebrate, were in July/August when they are typically inshore and feeding on shellfish.

Fifty-four specimens of the commercially important American lobster (Homarus americanus) were captured in 1991. This equals 944 lobsters impinged on an annual basis at 100% operation of Pilgrim Station, under conditions at the times of impingement. This is a much larger number of lobsters impinged than in recent years. The lobsters ranged in size from 25-87 mm carapace length.

Approximately 2,880 pounds of mixed algae species were collected during 1991 impingement sampling for a rate of 5.7 pounds/hr. This equates to 25 tons of algae annually on Pilgrim intake screens. As expected, this rate is considerably higher than the 1984, 1987 and 1988 outage years and comparable to 1989-1990 because of regular circulating water pump availability during the last three years.

4.3 Fish Survival

Fish survival data collected in 1991 while impingement monitoring was conducted are shown in Table 9. Static screen wash collections provided the greatest numbers of fishes and revealed an overall survival rate of approximately 57%. Fishes collected during continuous screen washes fared about the same showing a survival rate of 50%. The relatively high initial survival rate for static screen washes, compared with most previous years, was influenced by the high initial survival of Atlantic herring impinged during the July impingement incident; however, these herring were in various stages of viability and it was conservatively assumed, as historial data suggest, that all eventually succumbed. Typically fishes have a higher survival rate during continuous screen washes because of reduced exposure time to the effects of impingement. However, reduced intake currents in 1984, associated with limited circulating water pump operation, may have been a factor in higher static wash survival then because of less stress on impinged individuals; although this wasn't apparent from 1987 and 1988 limited pump operation results. Only initial survival rates are comprehensive because 1-hour and 56-hour data were rendered incomplete when survival pools were out of service, fishes were lost or samples were collected in the screenhouse during portions of 1991.

Among the ten numerically dominant species impinged in 1991, three demonstrated initial survival rates of 50% or greater. Winter flounder showed 78% survival, grubby 70%, Atlantic herring 63%, Atlantic silverside 33%, cunner 26%, alewife 17%, blueback herring 16%, Atlantic menhaden 13%, scup 11%, and rainbow smelt 2%.

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-December 1991. Initial, One-Hour and Latent (56-Hour) Survival Numbers Are Shown Under Static (8-Hour) and Continuous Wash Cycles.

Species	Number Collected		Number Surviving						Total Length (mm)	
	Static Washes	Cont. Washes	Initial Static	Initial Cont.	1-Hour* Static	1-Hour* Cont.	56-Hour Static	56-Hour Cont.	Mean	Range
Atlantic herrring	2,335	35	1,479	14	–	–	–	–	81	38-333
Atlantic silverside	264	11	85	5	–	4	–	2	105	72-143
Atlantic menhaden	113	0	15	–	–	–	–	–	78	52-131
Winter flounder	54	13	43	9	–	–	–	–	104	46-335
Grubby	38	8	24	8	–	1	–	0	80	40-110
Rainbow smelt	40	1	1	–	–	–	–	–	112	68-185
Blueback herring	29	2	5	0	–	0	–	0	91	75-126
Alewife	18	6	4	0	–	–	–	–	98	75-138
Cunner	21	2	5	1	–	1	–	1	120	45-176
Scup	18	0	2	–	–	–	–	–	60	40-88
Tautog	15	3	14	3	–	–	–	–	75	55-160
Atlantic tomcod	16	0	6	–	–	–	–	–	152	89-235
Northern puffer	15	0	10	–	–	–	–	–	78	42-135
Windowpane	7	4	5	4	1	0	1	0	77	40-104
Little skate	8	0	3	–	0	–	0	–	497	470-511
Striped killifish	6	1	4	1	–	–	–	–	87	76-96
Red hake	6	0	1	–	1	–	0	–	140	89-181
Rock gunnel	3	3	3	1	1	0	1	0	124	70-196
Lumpfish	5	0	1	–	–	–	–	–	56	40-83
Northern searobin	4	0	2	–	0	–	0	–	248	240-255
Pollock	4	0	0	–	0	–	0	–	60	51-70
Bay anchovy	3	0	0	–	–	–	–	–	73	53-85
Butterfish	3	0	0	–	–	–	–	–	40	37-42
Northern pipefish	2	1	0	0	0	0	0	0	140	140-141
Sand lance sp.	2	1	2	0	0	0	0	0	161	140-202
Silver hake	3	0	0	–	0	–	0	–	138	93-160
Striped searobin	3	0	0	–	0	–	0	–	96	96
White perch	3	0	3	–	–	–	–	–	83	60-108
Atlantic cod	2	0	0	–	–	–	–	–	81	72-89
Black sea bass	2	0	2	–	–	–	–	–	67	60-73
Fourspot flounder	2	0	2	–	0	–	0	–	318	318
Radiated shanny	2	0	2	–	–	–	–	–	97	85-108
Threespine stickleback	2	0	1	–	–	–	–	–	51	39-63
Hog choker	0	1	–	0	–	–	–	–	126	126
Mummichog	1	0	1	–	–	–	–	–	66	66
Northern kingfish	1	0	0	–	–	–	–	–	200	200
Shorthorn sculpin	1	0	0	–	–	–	–	–	86	86
Smooth dogfish	1	0	1	–	1	–	0	–	781	781
Spiny dogfish	1	0	1	–	–	–	–	–	915	915
All Species:										
Number	3,053	92	1,727	46	–	–	–	–		
(% Surviving)			(56.6)	(50.0)						

* Limited data for species because survival pool was frozen, or fishes were lost or sampled in the screenhouse.

SECTION 5

CONCLUSIONS

1. The average Pilgrim collection rate for the period January-December 1991 was 6.27 fish/hour. The impingement rates for fish in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1991 because of much reduced circulating water pump capacity during the former years.

2. Thirty-nine species of fish were recorded in 501.25+ impingement collection hours during 1991. In 1985, 1986 and 1989 - 1991 several times the number of fishes were sampled as compared to 1984 and 1988, despite more collection hours in 1984 and an average number of hours in 1988. This illustrates the importance that the number of circulating pumps operating has on the quantity of impinged organisms. Substantially less collecting hours for portions of 1987 precluded its comparison with other years.

3. At 100% yearly operation the estimated maximum January-December 1991 impingement rate was 54,925 fishes (784 lbs.). This projected annual fish impingement rate is the highest since 1981 at Pilgrim Station.

4. The major species collected and their relative percentages of the total collections were Atlantic herring, 75.4%; Atlantic silverside, 8.7%; Atlantic menhaden, 3.6%; winter flounder, 2.1%; and grubby 1.5%

5. The peak in impingement collections for Atlantic herring occurred during June and July. Atlantic herring hourly impingement rate per month varied from 0 to 24.44.

6. A large, fish impingement incident occurred from July 22-25 involving Atlantic herring, when a rate of 52.29 fish/hr. resulted in an estimated mortality of approximately 4,200 juvenile herring.

7. Monthly intake water temperatures, which generally reflect ambient water temperatures, were mostly warmer the first half and colder the second half of 1991 than the ten-year monthly averages for the period 1982-1991. May and June mean water temperatures were higher, and August and September lower than any recorded in the last ten years for these months.

8. The hourly collection rate for invertebrates was 1.40+. Jellyfish (undetermined numbers) dominated because of large July and August collections. Blue mussels were collected in large numbers during May, and common starfish and sevenspine bay shrimp were 25.4 and 23.3% of the enumerated catch. Fifty-four American lobsters were collected which equates to a potential 1991 impingement of 944 lobsters.

9. Impinged fish initial survival was approximately 57% during static screen washes and 50% during continuous washes for pooled species. Of the ten fishes impinged in greatest numbers during 1991, only three showed initial survival rates of 50% or greater.

SECTION 6

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SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS
IN WESTERN CAPE COD BAY
IN 1991

Prepared by: Robert D. Anderson
Robert D. Anderson
Senior Marine Fisheries
Biologist

Regulatory Affairs Department
Licensing Division

Boston Edison Company

April 1992

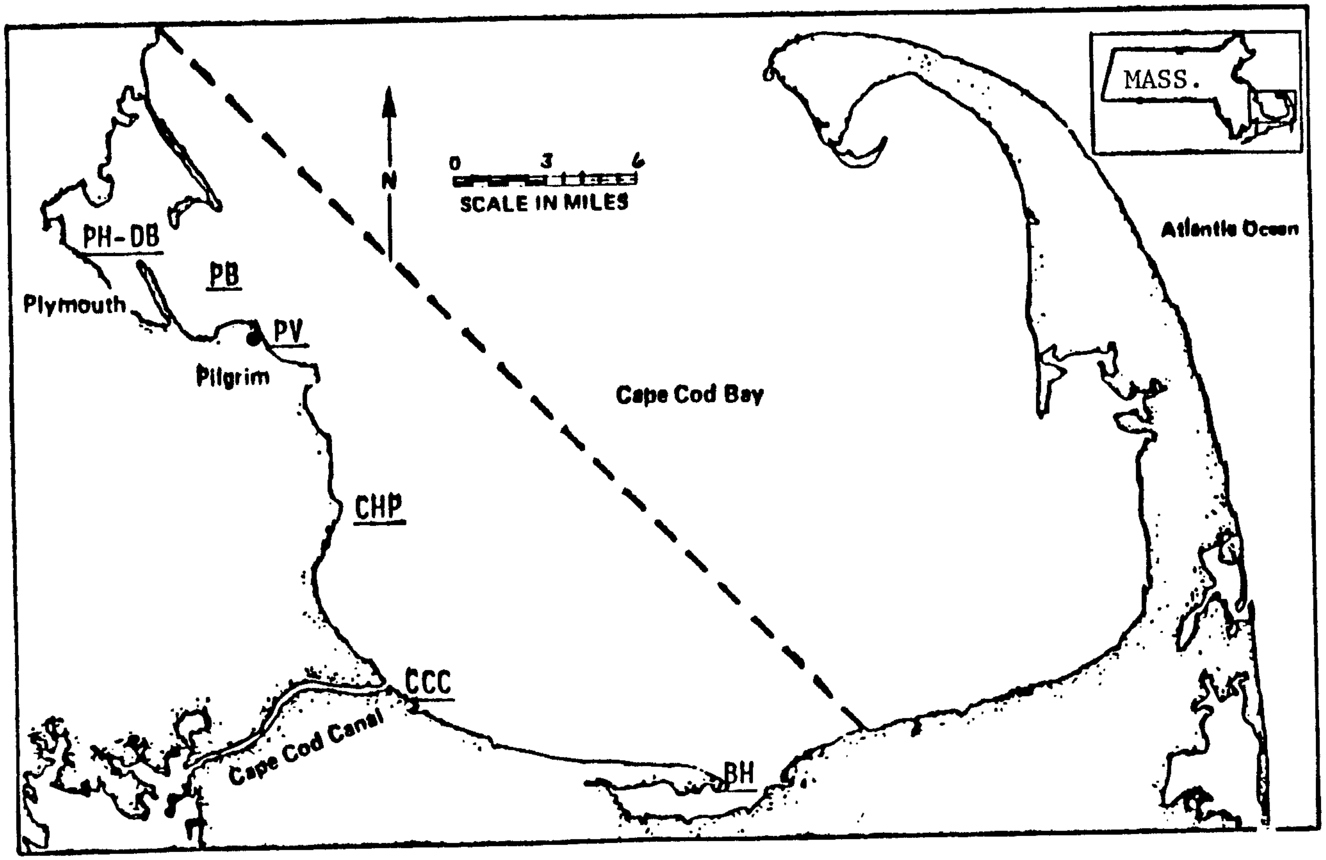
SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS IN
WESTERN CAPE COD BAY IN 1991

Weekly fish spotting overflights were made north, south and in the vicinity of Pilgrim Nuclear Power Station (PNPS) from March-November 1991. Four main groupings of fish were noted by the overflight pilot who was trained to spot fish for commercial fishing operations. The four groupings are: 1) herring, consisting primarily of Atlantic herring (*Clupea harengus harengus*), alewife (*Alosa pseudoharengus*) and/or blueback herring (*Alosa aestivalis*); 2) Atlantic menhaden (*Brevoortia tyrannus*); 3) Atlantic mackerel (*Scomber scombrus*); and 4) baitfish, consisting primarily of any species too small to identify but most likely being composed of Atlantic silverside (*Menidia menidia*), rainbow smelt (*Osmerus mordax*), sand lance (*Ammodytes* spp.) or the juveniles of other species. In addition, sightings of other marine species, such as bluefish (*Pomatomus saltarix*) or whales (Cetacea), are occasionally reported.

Figure 1 shows the general area covered by the PNPS fish overflight program, although reports of fish concentrations are received from further north or south, also. Plates 1 and 2 show an overflight airplane and a typical fish school as it appears when viewed from the airplane.

This summary report is meant for general information purposes only, as it is not possible to quantify with reasonable accuracy the data from this qualitative a program. Nevertheless, this program is very valuable and useful in being responsive to NPDES Permit requirements, documenting barrier net effectiveness when confirming large quantities of fishes in the Pilgrim area, and alerting Boston Edison Company and regulatory personnel of the potential for a discharge-related fish mortality.

Figure 1. FISH SURVEILLANCE OVERFLIGHTS (Critical Area)



PH-DB	Plymouth Harbor-Duxbury Bay
PB	Plymouth Bay
PV	Pilgrim Vicinity
CHP	Center Hill Point
CCC	Cape Cod Canal
BH	Barnstable Harbor

Note: Critical surveillance area is west of the dashed line in the vicinity of the specific locations noted. Generic observations should also be made in the course of the plane's flight to and from the critical area.

Plate 1. The airplane used for fish spotting overflights in the Pilgrim Station area is typical of the ones used in commercial area fishing operations.

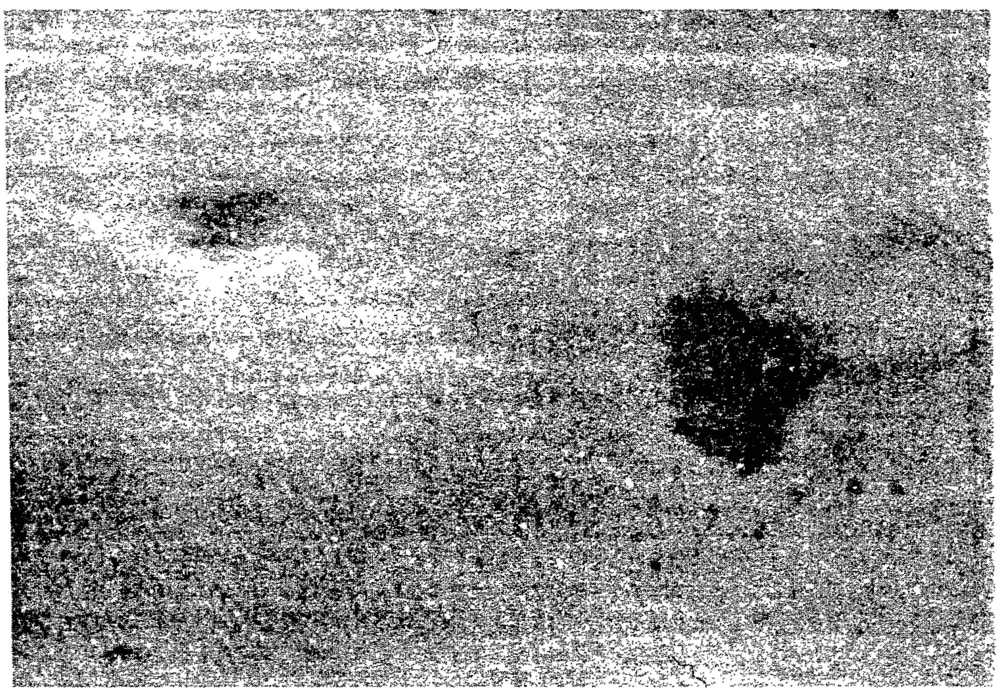


Plate 2. A fish school appears as a dark shadow from the airplane, and it takes an experienced pilot to distinguish its composition from submerged objects.

Table 1 summarizes location, approximate poundage and seasonal information for the four groupings of fishes defined above. Below are some interpretive comments based on general trends illustrated by fish observation data for the four predominant fish groups from March-November 1991:

1. Herring - This is a mixed species category, but the majority of pounds of herring observed by fish overflights represents Atlantic herring as borne out by commercial catch statistics. This species was in the Cape Cod Bay region during most of the observation period, primarily in the vicinity of PNPS. The alewife and blueback herring were prevalent on August 3 when 70,000 pounds were spotted 1 mile east of PNPS. However, most of the herring observed during August were Atlantic herring. A relatively large number of sightings were made of Atlantic herring during 1991 in the vicinity of PNPS, possibly reflecting population fluctuations for this species. Eight observations of Atlantic herring within a few miles of PNPS were made during 1991, including over 100,000 poundss on two dates, August 15 and 24. No fish mortalities occurred, although in November 1976 over 10,000 Atlantic herring were killed by impingement on PNPS intake traveling screens.

2. Atlantic Menhaden - This species is of concern at Pilgrim because of past gas bubble disease mortalities in the discharge canal and thermal plume. As can be seen from Table 1, menhaden may occur over the entire Cape Cod Bay region in millions of pounds from spring through early fall. Overflight pilots are particularly adept at

TABLE 1. Approximate Location, Relative Species Poundage and Seasonality from Fish Observation Overflights in the Western Cape Cod Bay Area in 1991

LOCATION	SPECIES	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
North of Pilgrim	Herring		283,000						25,000	180,000
	Menhaden		60,000	2,175,000	883,000	657,000	1,502,000	475,000	258,000	
	Baitfish									
	Mackerel	6,000	18,000	10,000	62,000	8,000	2,000			
Pilgirm Vicinity	Herring	24,000	40,000			160,000	375,000	40,000	30,000	
	Menhaden				300,000			2,000		
	Baitfish									
	Mackerel				60,000					
South of Pilgrim	Herring		52,000					25,000		
	Menhaden		140,000	210,000	300,000	280,000				
	Baitfish		10,000		30,000					
	Mackeral					45,000	76,000			
Totals	Herring	24,000	375,000			160,000	375,000	65,000	55,000	180,000
	Menhaden		200,000	2,385,000	1,483,000	937,000	1,502,000	477,000	258,000	
	Baitfish		10,000		30,000					
	Mackeral	6,000	18,000	10,000	122,000	53,000	78,000			

*Regulators notified (EPA/DWPC).
+Unestimated poundage.

identifying this species as commercial ventures depend heavily on accurate observations for success. The first menhaden north of Cape Cod in 1991 were observed on April 29 in Duxbury Bay. The great majority of menhaden were sighted north of PNPS from May through September. Menhaden were spotted in the PNPS vicinity on June 26 (300,000 pounds) and in the PNPS intake embayment on September 30 (2,000 pounds). Regulatory agencies (EPA and Mass. DWPC/DMF) are notified when fish are within 1/2 mile of the point of thermal discharge into Cape Cod Bay. The last menhaden observed in 1991 were 29,000 pounds in the Plymouth Bay-Duxbury Bay area on October 17.

3. Atlantic Mackerel - These fish support a valuable commercial fishery and are generally reported in greatest numbers south of PNPS. In 1991, there were several observations made of Atlantic mackerel schools mostly from April - August with largest quantities seen in June. There was one sighting close to PNPS when 60,000 pounds were spotted within a couple of miles of the Station discharge on June 26.

   Mackerel occur in relatively large numbers usually during the Summer - early Fall months, and no notable incidents involving them have occurred at Pilgrim Station. They are an offshore species for the most part but have been observed in previous years schooling in the PNPS intake embayment, where bluefish predation on them has occurred.

4. Baitfish - This category is a catchall and may include large numbers of small unidentified fish. In April and June several thousand pounds of sand lance were seen off Barnstable Beach with bluefish

noted feeding on them during the latter month. Sand lance, as well as most species in this grouping, regularly inhabit the PNPS intake area in numbers too small to be seen by overflights but recorded during seine net sampling from the intake beach.

Baitfish could represent the offspring of fishes in the above categories as well as Atlantic silversides, rainbow smelt and sand lance. Some of these species are significant in impingement collections at PNPS.

5. Other - There were several other spottings made in 1991 which fall outside the above categories. Included were bluefish, whales (finback & humpback), striped bass, sharks (basking) and tuna. Those species seen in the proximity of PNPS included striped bass and 2 finback whales in March; and bluefish (74,000 pounds) in June.

The Commonwealth of Massachusetts
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PHILIP G. COATES
DIRECTOR

MEMORANDUM

888-1155

TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations

FROM: Brian Kelly, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 76th meeting of the Pilgrim Administrative-Technical Committee

DATE: October 9, 1991

The 76th meeting of the Pilgrim Administrative-Technical (A-T) Committee was called to order by Chairman Szal (DWPC) on September 26, 1991 at 10:10 a.m. at the Richard Cronin Building, Massachusetts Division Fisheries and Wildlife Field Headquarters, Westboro, Massachusetts. Seven agenda items were addressed.

I. Minutes of the 75th Meeting

There were no additional comments on the previous A-T meeting minutes, which were accepted unanimously.

II. Pilgrim Station Status Update

Bob Anderson reviewed 1991 Pilgrim Station power output. From January through April, the plant ran at 90% power. A refueling outage then ran from late April until late July. From late August through September, Pilgrim operated at near 100% power. A mid-cycle outage of four weeks duration is planned for fall 1992. Pilgrim approached its maximum ΔT of 32° F in September and had to reduce power up to 20% at times to stay within their limit. An impingement of approximately 4,000 juvenile Atlantic herring occurred between July 22-25, the first major impingement mortality at Pilgrim since 1981.

A discussion ensued of possible modifications to be made to the Brayton Point Power Plant barrier net to prevent a repeat of the recent striped bass mortality there; the relative success of the Pilgrim barrier net was mentioned.

III. 1992 Marine Fisheries Monitoring

Bob Anderson presented the Division of Marine Fisheries proposal as summarized in Jack Finn's Fisheries subcommittee minutes. Commercial lobster monitoring will remain unchanged. With the research lobster study, there was a discussion whether the present location of Station E is measuring plant discharge effects (heat and current) in a manner similar to Stations F, G, and H, as previous studies show the thermal plume to detach from the bottom at about 600 feet from the discharge canal. DMF may relocate Station E slightly closer to the discharge in the future, but present station locations are dictated by gear constraints, bottom topography, and by an effort to get estimates of catch variability within the heterogenous impact area.

Vincent Malkoski reviewed the rationale for and workings of the modified sampling strategy for demersal fish. The use of diver transect surveys, as done in Puget Sound, was explained, wherein underwater observations will focus on the dominant groundfish of the area (flounders and skates). Dives will be conducted at each of the trawl station sites, with the exception of Warren Cove, from April through November. Trawl sampling will continue in 1992 at all four sites to maintain the database. If diving transects prove to be a viable data collection technique, the trawl program may either be diminished or dropped in 1993.

The shorezone fish haul seine program will be discontinued for 1992. It may be reinstituted if Pilgrim's operating capacity increases in the future. A final report summarizing the ten years of seine data will be prepared in 1992; DMF will also complete an Irish moss final report.

Vin informed the Committee of DMF's attempt to refine the quantitative data obtained from their diving observations by utilizing techniques reported in use at coral reefs. Bob Lawton updated the Committee regarding progress with the cunner tagging study. Preliminary diver observations of tagged cunner and localized movements of this species were discussed.

Bob Maietta moved to accept the DMF proposal as presented, which passed unanimously.

IV. 1992 Impingement/Entrainment/Overflight Monitoring

Bob Anderson also presented these other monitoring proposals. Fish overflights will continue without change in 1992. For the impingement study, long-term survival (one and 56-hour) will not be determined; the conservative assumption of 100% mortality will continue.

As part of the entrainment study, Bob Anderson will request Mike Scherer of MRI to (1) research the state-of-the-art of adult equivalency model analysis to report to the full Committee and (2) investigate redefining the additional entrainment sampling protocol (presently set at a 50% increase per species from the highest year's value for a given month) as this entrainment value escalates over time to increasingly non-conservative levels. Bob will arrange a special meeting of the full Committee in early December 1991, at which time Mike will present his findings and recommendations for discussion by the Committee.

Jerry Szal moved to accept the impingement and overflight studies as recommended by the fisheries subcommittee and to accept the entrainment study with the stipulation of discussing the adult equivalency issue at a special Pilgrim A-T meeting in December. These motions carried unanimously.

V. 1991 Special Benthic Monitoring Update

Jerry updated the Committee on the progress of benthic monitoring efforts in 1991, based on a memo from Don Miller. Whitlatch and Osman's team spent a weekend (September 13-15) diving at the Pilgrim Station discharge. They noted no stunted or denuded zones at the site. Divers deployed four sets of fouling panels at stations where temperature monitors will be set in early October. A late October trip will be made to pick up the panels and temperature monitors. The Committee requested Don to send the monthly updates received from Whitlatch and Osman of benthic work to all Committee members. There was concern expressed by Committee members as to exact locations of stations/temperature monitors, and how distances were measured (what was the fixed reference point utilized?). Bob Anderson will request Don Miller to clarify these points with Whitlatch.

VI. 1992 Benthic Monitoring and Future Plans

Benthic quantitative studies will be discontinued in 1992, while the qualitative work will continue, as moved at the special A-T meeting of August 1, 1991. A special meeting of benthic ecologists will convene in early 1992 to discuss the retrospective benthic analysis and 1991 special benthic monitoring, and then make recommendations for 1993 benthic studies. Whitlatch is organizing the meeting. Some Committee members suggested that this panel of experts be sent Pilgrim semi-annual reports for review to acquaint them with the data, and give them some exposure to algal information, which was not addressed in the retrospective analysis.

VII. Other Business

Carolyn Griswold was nominated as the new chairperson of the Fisheries subcommittee; she graciously accepted. Jerry will write a letter of appreciation for the Committee to past Subcommittee chairman Jack Finn. The fisheries subcommittee needs new members, as Bruce Higgins has transferred to the Pacific coast. Carolyn will ask Jan Prager of EPA Narragansett, and Leigh Bridges will contact Joe Pelczarski of Massachusetts CZM to join the Subcommittee. Leigh will also make a request of UMASS Amherst.

There was a discussion of the proposed secondary treatment disposal pipe off Rocky Point and resultant complications on the monitoring effort at Pilgrim.

VIII. Adjournment

The meeting adjourned at 2:30 PM.

Pilgrim Administrative-Technical Committee Meeting Attendance

September 26, 1991

Gerald Szal, Chairman	Mass. DEP, Grafton
Ted Landry	EPA, Boston
Robert Maietta	Mass. DEP, Grafton
Carolyn Griswold	NMFS, Narragansett
Robert Anderson	BECo, Braintree
Leigh Bridges	Mass. DMF, Sandwich
Robert Lawton	Mass. DMF, Sandwich
Vincent Malkoski	Mass. DMF, Sandwich
Brian Kelly	Mass. DMF, Sandwich (recording secretary)

The Commonwealth of Massachusetts

Division of Marine Fisheries

18 Route 6A

Sandwich, Massachusetts 02563

PHILIP G. COATES
DIRECTOR

888-1155

MEMORANDUM

TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations

FROM: Brian Kelly, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the Emergency Meeting of the Pilgrim Administrative-Technical Committee

DATE: December 17, 1991

An emergency meeting of the Pilgrim Administrative-Technical (A-T) Committee to discuss both adult equivalency theory and the benthic monitoring program was called to order by Chairman Szal (DWPC) on December 5, 1991 at 10:15 a.m. at the Richard Cronin Building, Massachusetts Division Fisheries and Wildlife Field Headquarters, Westboro, Massachusetts.

Don Miller gave an overview of past quantitative benthic monitoring efforts at Pilgrim Station, which led into the current study being conducted by Bob Whitlatch and Rich Osman. Don passed out copies of Whitlatch's progress update, and reviewed the contractor's progress to date. The initial benthic survey work done in September was not in the historically defined stunted zone; panels set out were destroyed in a late October storm. Three panel arrays with acoustic pingers and temperature recorders were placed at 50 m, 100 m, and 150 m from the discharge canal in late November, and will be retrieved in late December.

Don stated that if the plume is lifting off at the end of the present stunted zone, then the plume influence is low and the monitoring effort should be defined accordingly. A discussion of the plume mixing zone and problems associated with measuring temperatures and currents within it followed. Steve Halterman mentioned he had a temperature profiler available for such work. The Division of Marine Fisheries and Division of Water Pollution Control will attempt to do current and temperature profiles of the Pilgrim plume this month. Don suggested superimposing depth with temperature on scour zone maps, and to supply these data for the upcoming benthic panel meeting. Bob Anderson requested delaying the benthic expert panel meeting beyond January, as Whitlatch first needs to produce a comprehensive final report of their fall activities and data analyses for review by the Benthic Subcommittee. The Committee decided on a mid-March panel meeting date to allow time for review of Whitlatch's report, and also to allow time for any panel-recommended summer benthic monitoring program to be designed, bid on, and implemented. All Committee members are invited to attend this meeting. Anderson will investigate holding the meeting at the Pilgrim I and E building; panelists will be polled regarding their availability for mid-March.

Mike Scherer accompanied his information session on Adult Equivalency (AE) with a handout containing key equations relating to its mathematical development by Horst and Goodyear. A discussion followed on the accuracy of AE analyses; Scherer emphasized that the strength of an AE depends on the accuracy of survival estimates for a species. Jack Parr mentioned biologists can use a range of larval survival (0%, 50%, 100%) and then see after running model if the AEs are of concern. Scherer concurred that AE can be used as a screening tool and if numbers look above what regulators can accept then more sophisticated modelling can be designed. A discussion on the status of coastal fish stocks in the northeast and overfishing followed.

Anderson suggested looking at doing an AE for a few species at Pilgrim Station. After some discussion, the Committee felt cunner was the most appropriate species to center on, due to its localized distribution and high entrainment numbers. Winter flounder will also be investigated; Scherer will look at Pilgrim entrainment numbers to recommend a third species, most likely Atlantic herring or mackerel.

Russ Isaacs requested Leigh Bridges hold a meeting in the near future at Cat Cove to discuss the cumulative effects of power plants on coastal resources. Dependent on the results of any AE study and this meeting, regulators may reallocate their biomonitoring efforts and change their way of thinking.

The Committee discussed the importance of study consistency in relation to contractor longevity. Bob Maietta made the motion that the A-T Committee recommend that the following contractors who have done studies At Pilgrim Station in the recent past continue to do them this year and future years to maintain scientific integrity and consistency of results/analysis:

(1) Division of Marine Fisheries - marine fisheries monitoring

(2) Marine Research Inc. - impingement/entrainment monitoring

(3) SAIC - qualitative benthic monitoring

(4) Correggio Spotting Service - overflight monitoring.

Jerry Szal seconded the motion, which passed unanimously.

Bob Lawton stated that the Fisheries Subcommittee needs new members for a more thorough review of monitoring programs. Miller suggested paying someone from academia to serve on the Subcommittee if state or federal people cannot be found. Carolyn Griswold will check with Vaughn Anthony for someone to volunteer from NMFS, while Leigh Bridges will ask UMASS Amherst now that the teaching positions there have been filled several months.

The meeting adjourned at 1:10 PM.

Pilgrim Administrative-Technical Committee Meeting Attendance

December 5, 1991

Gerald Szal, Chairman	DEP, Westboro
Donald C. Miller	EPA, Narragansett
Carolyn Griswold	NMFS, Narragansett
Jack Parr	EPA, Waltham
Leigh Bridges	DMF, Boston
Robert Anderson	BECo, Braintree
Robert Lawton	Mass. DMF, Sandwich
Russ Isaacs	DEP, Boston
Steve Halterman	DEP, Boston
Robert Maietta	DEP, Grafton
Brian Kelly	Mass. DMF, Sandwich (recording secretary)
Mike Scherer	MRI, Falmouth (guest)